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PAVLOV
AND HIS SCHOOL



FIG. 1. I. P. PAVLOV IN 1912

PAVLOV AND HIS SCHOOL

The Theory of Conditioned
Reflexes

BY

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AUTHOR'S FOREWORD

IVAN PETROVICH PAVLOV is dead. It is difficult to realize that the work of this brilliant mind, engaged for so many decades in ceaseless creative activity, has now come to an end.

Pavlov and life—knowledge of life, joy in life—were inseparable ideas. And yet death has come in between!

When a man of such gigantic power of thought and will as Pavlov passes away, it appears as if nature were taking revenge on us for our inability to read her still undiscovered secrets.

Quite recently, Pavlov, full of vigour and enthusiasm, was saying that he would like to live another fifteen years so that he might by his own exertions bring to a conclusion the great investigation begun by him into the higher nervous activity of animals and man. His claim to the right to live took into account, not his age, but the needs of his scientific work.

On falling seriously ill last year, he never ceased for a moment to study the working of his own brain. Even during illness his exceptional powers of observation never deserted him.

There are indications that even during his last illness, the one that brought him to the grave, Pavlov was occupied with thoughts of his favourite chapter of natural science, the problem of higher nervous activity. He fulfilled his duty to science

to the very end, to the last gleam of his waning consciousness.

It may be that we are still powerless to combat old age and death in human beings. History will perform what at present cannot be done by physiology and medicine. Successive generations, reading Pavlov's works, studying Pavlov's many-sided and clear personality reflected in them, will feel that he will always remain alive, and his name will be associated in their minds with the image of a scientist unlimited in his devotion to the idea of the triumph of science and the happiness of toiling humanity.

The surging cataract of energy which we know by the name of Pavlov has only stopped for a moment, frozen by death. But afterwards, what will happen? Afterwards, this vigorous stream will flow again, this time as a broad and smoothly flowing river which will become a wide highway and freely open path for all those who desire to dedicate their life and passion to the service of science, to the struggle against ignorance and mysticism.

The majority of his bereaved pupils are now actuated by only one idea: to sleep themselves in the everyday work of the laboratory that Pavlov so much loved and to occupy themselves with organizing new experiments, so that by their collective labour the breach inflicted on their ranks may be made good.

To extend the physiological study of cerebral activity, the basis for which was laid by Pavlov himself, to select a suitable setting for the jewels of thought that are to be found in the works of the great teacher—this is what we consider our duty,

we who have been privileged to participate in the tremendous scientific enterprise begun by Pavlov.

This book was written while Pavlov was still alive, but owing to preoccupation with work in the laboratory we made no special efforts to expedite its publication, especially as we hoped for a preliminary consultation with Pavlov on a number of the questions dealt with. Unfortunately, this was destined not to be.

It is difficult to finish and edit a book on Pavlov, on his work, his school and his remarkable personality, just at the moment of the rupture of all those powerful bonds which had been established during twenty-three years' contact with him. Nevertheless we consider that it is necessary, since there are many at the present time, even though not physiologists or even biologists, who are undoubtedly desirous of knowing what was the scientific aim pursued by Pavlov in his works. In regard to the study of cerebral activity, they desire to know something of its origins and historical developments, the means that Pavlov employed for his work and the chief conclusions at which he arrived.

Pavlov is in truth to be numbered among the classical scientists. Consequently he cannot be considered in isolation from the whole history of natural science; his theory of higher nervous activity cannot be considered in isolation from the growth and development of other branches of science.

Of all the sciences dealing with the laws of the world surrounding us and of our own being, the fundamental place is undoubtedly occupied by *physics*. Pavlov valued this science very highly.

On studying the history of our knowledge of the physics of the world about us, one feels here more than anywhere else the tremendous power and fruitfulness of the scientific method. Each new conquest of physics, of course, widens the basis on which other, younger sciences have been built. Physics, more than any other scientific discipline, explains the meaning and significance of basic conceptions and contains in itself the prerequisites for the objective investigations undertaken by other sciences founded on experiment.

At the same time, physics with its precise measurements of space and time, with its modern theory of the structure of matter, with its methods making it possible to detect and utilize ever new forms of energy, ensures the establishment of new relations between human beings and their environment, and, in the last analysis, the transformation of this environment.

The same thing fully applies to the modern science of chemistry, in particular physical chemistry which is the basis for so many branches of our knowledge.

As regards the position of other, relatively young fields of natural science, in particular the sciences of living organisms, including the *physiology* of animals and man, they labour under incomparably more difficult conditions, although present-day physics and chemistry endeavour to lighten the burden of physiology to a significant extent by working towards the solution of the problem of the structure of living matter. During the first part of his life, Pavlov devoted much time to the study of the chemistry of ferments.

Modern bio-physics and bio-chemistry are already

very valuable fields of knowledge on which practical medicine and hygiene can draw to a very large extent for making life more healthy and for enhancing the nutritive value of foods, and so on.

There is, however, one field in physiology where pessimistic conclusions and predictions are more frequently encountered than in any other section of biology. Such was the state of things, at least, until Pavlov applied here the searchlight of the method discovered by him.

We refer to the field of the phenomena connected with the activity of the higher parts of the nervous system in animals, and especially in man. The difficulties encountered by the investigator in this field are undoubtedly the result of the complexity and diversity of the activity of this most complicated system. But a certain proportion of the failures must be attributed to the investigators themselves, who have found it difficult to break with the traditional views acquired from Plato and Aristotle, views which put the study of the body in sharp contrast to the study of the mind.

As is well known, even Descartes did not succeed in overcoming this contradiction in the problem of life. In relation to life, he was a dualist and regarded thought as the exclusive property of human beings, while considering animals as mere automatons.

It will soon be the three hundredth anniversary of the appearance of Descartes' *Discourse on Method* (1637). This anniversary will find psychology in a state of vigorous development. A vast number of research laboratories and institutes throughout the world are investigating the basic problems and working out new methods for obtaining knowledge

of nature. However, the key points and problems of psychology remain approximately the same as in the time of Descartes.

Although Descartes' views now appear to us to be naïve, nevertheless the three centuries separating us from him have not witnessed the solution in full of a single one of the questions which confronted him. It must be recognized in this connection that Descartes did much more to advance geometry and optics than he was able to do for biology or psychology by his theory of the passions. One of his conceptions, however, the theory of reflexes, has acquired exceptional significance in the further development of physiology.

History can name only two or three biologists who have displayed a full understanding of the significance attaching to objective analysis of the substratum of thought, viz. the brain. Among them undoubtedly is Charles Darwin, who on the basis of a vast number of observations and experiments founded the famous theory of the origin of species by natural selection and who left us a model of scientific research in his book *The Expression of the Emotions in Man and Animals*. Since Darwin's time, the significance of the struggle for existence in nature has become indisputable and obvious to all. Thanks to the numerous works of Darwin himself, and in particular owing to the works of his successors, many fields of science, including physiology, have taken on a completely new aspect. They have begun to depend, not on opinions and hypotheses, but on the general body of facts that have been verified by numerous investigators. Since Darwin's time, experiments with animals have been made on

a vastly extended scale. This has given rise to the modern theories of the functions of the muscles, heart, lungs and digestive organs, which Pavlov examined with such detail and genius during the first part of his life.

We might be inclined to consider these achievements as exhaustive were it not for the fact that the region mentioned above, the field of the activity of the brain, remained a sort of forbidden territory to the scientist and one outside the scope of his experiments. For indeed one could not call by this name those purely external observations on the form and surface of the brain, its weight and anatomical connections, which help comparatively little towards understanding the complicated functions of the separate regions of the brain and their individual cells.

By studying Darwin's works, one can convince oneself that the activity of the spinal cord, and particularly of the brain, checked him by its complexity. At the same time, very important circumstances impelled Darwin's contemporaries to make a more detailed study of the physiology of the central nervous system, since on this depended very largely the success of the whole theory of evolution.

The progress of botany and ecology led to investigators like Sachs and Loeb studying the very simple reactions of organisms known as tropisms, *i.e.* positive and negative movements of a living organism in relation to stimulating objects (approach to food, flight from danger). More attention began to be paid to the activity of invertebrates, the physiology of the nervous system began to be investigated, physiology began by *objective* means to study the external marks of behaviour in animals. Material

for the study of behaviour can, of course, be found on all sides.

If one comes in contact with the body of a Medusa (jelly-fish) swimming freely in water, one experiences a peculiar burning sensation like that produced by a nettle. The electric fish gives a powerful electric discharge on contact. If a mosquito buzzes about you, making ready to plunge its proboscis into the skin, or if at dead of night you are pursued by a pack of wolves—in each case, however great the difference between the mosquito and the wolf in their organic structure and means of attack, a complicated system of *muscular* mechanisms is at work.

These forms of activity, however, do not at all exhaust the means of attack and defence exhibited by animals in the struggle for existence. The contents of the oral cavity in mammals, and particularly the *saliva*, also represent an essential means for preserving the life of the animal, moistening food that enters the mouth and washing the mucous membrane free from irritating substances. It may be recalled that the poison fangs of snakes also represent a form of salivary gland and, like all executive organs playing a part in the struggle for existence, they are regulated by the central nervous system.

This nervous system is affected by the varying activity of the so-called glands of internal secretion (the suprarenal glands, thyroid gland, etc.). On the other hand, it is itself capable of strengthening or weakening the activity of these glands. Thus we obtain an intricate maze of relations from which those who are pessimistically inclined refuse to see any possibility of finding an exit.

Pavlov, however, in 1895 began his investigations by the very simple analysis of the activity of the salivary gland, a gland that historically has played the part of Ariadne's thread, and so arrived at last at a physiological understanding of the highly complex phenomena taking place in the animal brain. He continued his study of higher nervous activity on the basis of the cerebral functions of healthy and sick human beings.

Pavlov always emphasized that the physiology of higher nervous activity has by no means said its last word. It is still one of the youngest chapters of natural science, although one progressing with gigantic strides.

The tremendous superiority of Pavlov's method of investigating higher nervous activity lies in the fact that from the start it makes it possible to arrange the problems of research into the intricate complex of cerebral functions in a definite order, and enables the investigator to make a preliminary careful survey of the new sphere of knowledge and to reveal the many strata of historically accumulated errors by always adhering to the principle "from the simple to the complex," the principle to which we owe our achievements in the fields of physics, chemistry and other exact sciences.

Pavlov supposes that the ideal of humanity lies not behind us, in the mists of the past, but in front of us, in our labour, in our work for subjugating the forces of nature. He says:

"The time will come, even if it be remote, when mathematical analysis, based on natural scientific analysis, will embrace in its magnificent formulæ all these equilibria, including finally also life itself."

Chapter I

PAVLOV'S IMMEDIATE PREDECESSORS : SECHENOV AND THE BEHAVIOURISTS

I. M. SECHENOV AND HIS VIEW OF CEREBRAL ACTIVITY

PAVLOV's predecessor, I. M. Sechenov, was the father of Russian physiology. He carried out a great deal of work, not only in Russia but also abroad. He was a close friend of the physiologist K. Ludwig and was on intimate terms with such men as the chemist Mendeleyev, the biologist K. A. Timiryazev and the clinician S. P. Botkin. Moreover, he did not stand aloof from the wider social movements of his time.

The towering figure of Sechenov stands at the point of intersection of many paths of development in Russian science and is familiar to all who are acquainted with the history of Russian natural science during the second half of the nineteenth century. Unfortunately it was not until 1935 that a collection of Sechenov's writings were translated into English for the first time, and up to now the majority of non-Russian workers in the fields of biology and psychology have been unacquainted with many of his most important ideas.

It is worth while at the outset to give a few chronological data. In 1859, when Darwin's *Origin of Species* appeared, Sechenov was already thirty years of age and had finished the work for his doctor's dissertation during his stay in Vienna.

Taking everything into account, however, it seems that Darwin's idea of evolution made a greater impression on Sechenov in the interpretation given it by Herbert Spencer, perhaps because Spencer regarded evolution not only from the point of view of the origin of species but also in its relation to the origin of *psychical* faculties, a subject in which Spencer was greatly interested.

Spencer's book, *The Basis of Psychology*, was published in July 1855, four years earlier than Darwin's *Origin of Species*.

A further circumstance, which undoubtedly played an important part, was that not long after this (in 1863) Sechenov discovered a new fact about the cerebral activity of animals, viz. the *inhibition* of certain reflex movements of decerebrate frogs under the influence of excitation of the middle brain by an electric current or the application of small salt crystals (the so-called *central* inhibition of reflexes which has ever since been called after Sechenov).

This discovery, coinciding with certain fortunate events in Sechenov's private life, took place during a period of big scientific discoveries, and so encouraged him that he ventured on a step which would be regarded as very risky by the majority of scientists and one not altogether characteristic of a physiologist. It was a step, however, that had very important and fertile results precisely in the field of the physiology of the brain. This step consisted in the publication by him of an original treatise after the manner of Descartes' *Discourse on Method*.

Sechenov's work *Reflexes of the Brain* was published in 1863 in the form of a series of articles, and appeared as a separate book in 1866.

Pavlov was then only twenty years of age, but Sechenov's book made a profound life-long impression on him. Together with G. H. Lewes' *Practical Physiology* which Pavlov had read while still a boy, Sechenov's *Reflexes of the Brain* can be said to have determined the character of the work of the second part of Pavlov's life of research, when he passed from work on digestion to the investigation of the brain.

It is well known that the 'sixties of the last century were an epoch of exceptional development of Russian science and also of philosophical thought.

We have the authoritative testimony of K. Timiryazev that during this period Sechenov was the centre of attention of a wide circle of the liberal intelligentsia who now for the first time put forward a demand for the development of natural science, in particular biology, as being a powerful cultural force (Pisarev). Physiological controversies regarding the simple animal cell and its sensitivity engaged the attention of eminent persons at that time as much as any important economic problem. Sechenov once even quarrelled with his friend Botkin owing to a disagreement in their views on the subject of the cell.

It is sufficient to point out that the famous author of this period, viz. Turgenev, who so clearly depicted the downfall of the old "nest of gentlefolk," took Sechenov for his model as the most typical representative of the rising intelligentsia and embodied him in the character Bazarov. For the first time in the history of literature, the apple of discord between "fathers" and "sons" and the hero of a novel took the form of a young physician, a repre-

sentative of the intelligentsia of tsarist Russia in the 'sixties, not belonging to the privileged classes, who spent his time in the prosaic occupation of dissecting frogs. But Sechenov accomplished a great deal more than Bazarov with the latter's Buechner-like views on life; with his *Reflexes of the Brain* Sechenov laid the foundation for a new chapter in natural science—Pavlov's theory of higher nervous activity; at least, he was responsible for its origin in the immediate future.

By his work on the physiology of the brain, Sechenov not only dealt a blow to the old clerical view of the soul—with a boldness such as Descartes could not boast of—he also created something new, namely a harmonious theory of the evolution of psychical faculties beginning from simple reflexes and extending right up to the most complicated forms of psychical activity.

It can be easily understood that the enthusiasm of Sechenov and his fellow-thinkers was viewed with extreme disquiet by the tsarist government, which even imposed a prolonged ban on his book.

What is the essence of Sechenov's theory of cerebral reflexes? What is it that constitutes his great service to science? Sechenov, two years before the appearance of Darwin's book *The Expression of the Emotions*, in which Darwin first disclosed the laws of "useful associated habits," clearly and satisfactorily defined the significance of so-called higher acquired reflexes connected with the physiology of the cerebral hemispheres.

"We found," he remarks, "that the spinal cord invariably, *i.e.* compulsorily, produces a movement on excitation of a sensory nerve, and in this circum-

stance we saw the first sign of the mechanical nature of the activity of the spinal cord. Further development of the question has shown that under definite conditions (consequently not always) the brain too can act like a machine, its activity being manifested by a so-called involuntary movement."¹ Again he says:

"The infinite diversity of the external manifestations of cerebral activities can be reduced ultimately to one phenomenon—muscular movement. Does a child laugh at the sight of its toy, does Garibaldi smile when they expel him for excessive love of the fatherland, does a girl tremble at the first thought of love, does Newton create world-governing laws and inscribe them on paper—everywhere, in every case the ultimate fact is muscular movement."²

From this one can understand him making the following assertion:

"All psychical acts without exception, if they are complicated by an emotional element, take place by means of a reflex. Consequently all conscious movements arising out of these acts, *i.e.* movements that are usually called voluntary, are, strictly speaking, reflex movements."³

Sechenov repeatedly pointed out that the psychical activity of man finds expression in external signs. Nevertheless the laws of the external manifestation of psychical activity have as yet been extremely little worked out even by physiologists on whom, according to Sechenov, this duty devolves.²

His final conclusions thus become comprehensible.

¹ Sechenov, *The Physiology of Growth Processes*, 1876 (Russian).

² Sechenov, *Reflexes of the Brain*, 1876, p. 74. (See *Collected Works of Sechenov*, English edition.)

³ Sechenov, *Psychical Studies: Reflexes of the Brain*, p. 8 (Russian).

They form a highly interesting prophecy as to the further development of the science of the brain. Sechenov says :

“The new psychology will have as its basis, in place of the philosophizings whispered by the deceitful voice of consciousness, positive facts or points of departure that can be verified at any time by experiment. And it is only physiology that will be able to do this, for it alone holds the key to the truly scientific analysis of psychical phenomena.”

Sechenov demonstrated his qualities as a physiologist not only by discovering the special form of inhibition of reflexes named after him, the existence of which no one had previously suspected, at least in the central nervous system, but also by introducing a number of very important corrections in the existing theories of the activity of the brain and systematizing a vast amount of *factual* data in the fields of the physiology of the sense organs and psychology.

Without being afraid of the reproach of Cartesianism, Sechenov maintained that the idea of the mechanical character of the brain is a “treasure-house” for all scientists under all conditions, and thus obliged himself, as it were, to begin his exposition by comparing the development in the nervous system of voluntary and involuntary acts.

He did make this comparison, pointing out in the first place that from one aspect all purely reflex involuntary movements are purposive, while from another aspect all so-called psychical conscious acts are controlled by the same apparatus that controls the reflexes. The reflex arc, as is well known, consists of three parts. The *first* part begins at the

periphery in the form of the receptor organ and includes the centripetal (afferent) nerve. The *second* part of the reflex is represented by nerve elements in the central nervous system itself. The *third* part connects the central nervous system to the executive mechanism by aid of the centrifugal (efferent) nerve.

Thought, according to Sechenov's view, is nothing but an "*inhibited*" reflex, *i.e.* a reflex which has lost its last part.

Sechenov further points out that in regard to the manner of their origin also, reflexes and psychical acts are absolutely identical. He shows this both by comparison of certain acts of behaviour in animals and man, and by the study of human development from infancy to the adult state.

Here one can undoubtedly trace the influence on Sechenov of Herbert Spencer and the latter's well-known theory of the evolution of psychical faculties. Sechenov, however, was much more thoroughgoing in his conclusions than Spencer.

Sechenov's great merit is that he connected his theory with the development and evolution of the sense organs, and attempted in so doing to reconcile the views of the famous physicist and physiologist Helmholtz, whose lectures he had attended at Heidelberg, with Darwin's views on evolution. Sechenov interprets all this in the light of the Cartesian conception of the reflex in the altered form worked out by him and extended, moreover, to the brain, the functions of which he conceives in a purely materialistic way. Hence Sechenov's work is a weapon which, however imperfect, yet inspired very great fear in those who

ascribed a special position to the brain, not for the sake of making a more detailed investigation of it but for the sake of preserving its activities from the extremely "immodest" views of the nineteenth century scientists.

Later on we shall note the weak sides of Sechenov's theory of the brain; at the moment, however, what it is necessary to emphasize is the great significance of his mode of approach. His proofs were constructed with the help of the resources of contemporary physiology to a much greater extent than is the case with the works of Buechner and Vogt, who belonged to the camp of the mechanical materialists.

An immense service rendered to science by Sechenov is his theory of the role of the *joint* activity of the sense organs in the formation of the so-called *higher*, i.e. more abstract, notions of space and time or, in the language used by Sechenov, our complex reactions to space and time as special complex stimuli, many senses simultaneously participating in the formation of such reactions.

Further, one must not overlook Sechenov's exceptional share in bringing to light the so-called *concealed traces of stimulation* in the higher regions of the human nervous system. Sechenov considered these traces to be a factor governing our higher reflex activity (and as such he regarded our whole psychical life) on a level with external, real physical stimuli.

In pointing out the role of the *repetition* of external stimulation in the formation of all kinds of connections in the higher centres of the brain, *Sechenov undoubtedly came very close to the discovery of Pavlov's*

conditioned reflexes. The only reason that he failed to make this discovery was that he did not have at his command the method which would guarantee a completely objective attitude to manifestations of the mind, viz. the method of conditioned salivary reflexes which was discovered thirty years later by Ivan Petrovich Pavlov.

Sechenov was no stranger to the *statistical* method, which he employed in analysing the voluntary behaviour of human beings. This is the method which, as is well known, was widely used by the famous scientist *Francis Galton*, the founder of English psychology.

But even the sun has spots, and Sechenov's system is not devoid of weak points. Some of his views have been overthrown by the later developments of science.

One could mention, for example, his desire to understand and explain psychical life on the basis of Spencer's *general principles of organic evolution*, by means of the "disintegration" and "integration" of characteristics.

From the very beginning of his work, Sechenov attempted to cast aside all philosophy; he fought for the "independence" of natural science. He seemed to forget that many mighty intellects, from the time of Plato and Aristotle, have worked on the question of the mind, on its role in the theory of knowledge. Of the works of the psychologists, he himself confesses that he had read only the second-rate textbook of Beneke. "We are not philosophers . . .," he proudly proclaims in his *Reflexes of the Brain*.

Nevertheless, Spencer's outlook, on which Sechenov based himself, is far from being neutral

precisely *where philosophy is concerned*. In point of fact Spencer's neutrality is only apparent. Taking Spencer's views as the point of departure does not do away with the basic antithesis of the two philosophical trends, materialism and idealism.

By recognizing the gradual accumulation of mental qualities handed down from parent to child, Spencer arrives at the basic principle of the *idealist* school regarding the inborn character of all mental organization, and consequently the ultimate innateness of fundamental "ideas."

Hence it can be said that Sechenov failed to carry out the necessary reforms in the study of psychical phenomena not only because he had not at his disposal the appropriate *experimental* method of investigation of higher nervous activity, which only Pavlov was able to discover, but also because the methodological roots of his investigation were still too weak. In particular, he did not take into account the exceptional philosophical difficulties which are encountered.

Sechenov, like Helmholtz, was unable to give a precise answer to the question: Are our sensations actual copies, photographs, *i.e.* reflections, of objects and processes in nature, or are they only symbols, that merely give us information about what takes place in nature? In regard to this part of his theory, Sechenov's materialism is an insecurely grounded, inconsistent materialism.

BEHAVIOURISM: ITS HISTORY, ITS STRONG AND WEAK POINTS

Darwin, in his book *The Expression of the Emotions*, pointed out the distinction between activities de-

pending on "direct nervous influence" or, more simply stated, depending on the innate organization of the nervous system, on the one hand, and activities depending on habitual acquired characteristics, on the other. This idea was developed much further by the experiments of a number of American psychologists who studied the behaviour of animals and man without reference to subjective processes, and who came to be known under the general name of "behaviourists."

Besides Lloyd Morgan, well known for his book *Habit and Instinct*, one must mention here in the first place the talented investigator of behaviour, E. L. Thorndyke (*The Animal Intelligence*, 1898), to whom Pavlov gives priority in research in the field of higher nervous activity; further, R. Yerkes (*The Dancing Mouse*, 1907), J. Watson (*Psychology from the Point of View of a Behaviourist*, 1919) and a number of others. Useful associated habits became the subject of widespread scientific investigation. Behaviourism attracted enormous attention from teachers and physicians, and the movement attained a great development. During the thirty-five years that have elapsed since the foundation of behaviourism, there is hardly any class of animal that has not been the subject of investigation by behaviourists, not to speak of man in whose case researches on behaviour are numbered in hundreds.

Concerning the psychology of vertebrates, one must mention here the researches of Parker, Shelford and Severin on fishes, of Yerkes on frogs and (together with Lerner) on anthropoid apes, of Thorndyke on poultry, dogs and dog-headed apes, of Bingham on birds, of Johnson on dogs, of

Liddell on sheep, and of Coburn on pigs. Further, one must mention the innumerable works carried out on animals that are special favourites of the behaviourists, viz. white rats, such as those of Gunther, Richardson, Bassett, Barber, etc.

We cannot, of course, attempt here to give any comprehensive exposition of these investigations. We shall only remark that the principle common to all the researches of the behaviourist school is the principle of elaborating certain artificial animal reactions in response to various physical stimuli on the basis (or against the background) of certain inborn reactions or instincts. A stimulating agent that invariably evokes a definite external reaction on the part of the animal is usually selected for the experiment. An electric current is frequently used by the behaviourists as such a stimulus, causing the animal to avoid a particular portion of the area in which it is confined or to withdraw the stimulated part of the body, *e.g.* the paw. But food or shelter may also serve as the stimulus used for experiment. Any of these stimuli may be used by the behaviourists as a basis for experiment.

When the character and strength of the reaction thus obtained has been measured, a new physical stimulus is added against the "background" of the old and in connection with it, *e.g.* the sound of a bell or the flash of a lamp or the action of some other physical agency. As a result of a number of such experiments it has been found that the animal begins to exhibit an "electrical" reaction, *e.g.* it withdraws the paw or changes the usual path of its movement whenever the bell begins to sound or the light to flash out.

These experiments have furnished a vast amount of extraordinarily valuable material for characterizing certain aspects of animal behaviour; all this material is of a purely experimental kind, and it is just this that constitutes its advantage in comparison with Sechenov's work.

All the achievements of the behaviourists come under the conception of the principle of nervous activity which Darwin first formulated in his book *The Expression of the Emotions*.

Although the American authors referred to above are not at all in disagreement with Darwin, whether in point of departure or in the interpretation of the results obtained by them, they are still more reminiscent of Darwin's predecessor, the associationist Bain. Their experiments the behaviourists call experiments on "associative memory in animals," that is to say they adhere essentially to that psychological position which, although serving Darwin as a temporary refuge, never completely satisfied him as a strictly objective investigator of animal behaviour.

Pavlov, in the preface to his well-known work, *Lectures on Conditioned Reflexes*, pays a tribute to the American behaviourists, and in particular to Thorndyke. But he does not follow their example. Take, for instance, the fundamental fact which constitutes the basis for the theory of conditioned reflexes, viz. the fact of the formation of so-called *temporary connections* in the cerebral cortex of animals. It was known long ago, from the flourishing period of English psychology, that two events occurring simultaneously become connected by means of a time association.

The behaviourists have studied this problem in a variety of animals—they have, so to say, attacked it on a broad front. Pavlov, as we shall see later, restricted himself to only one object. Of recent years Pavlov has more and more frequently called the conditioned reflexes discovered by him a particular case of *association*. However, it is by no means merely a question of terminology. The point is that Pavlov's methods are more fundamental and enable a better approach to be made to the *inner* bases of behaviour, to the complex dynamics of the processes that take place in the brain at the moment when a particular psychological act occurs.

There is no doubt that the method of "trial and error," so widely used by the behaviourists in their analysis of animal behaviour and which consists in giving the animal the possibility of choice in the solution of a given task, the successful solution of the task being rewarded by food or freedom from confinement, clearly reveals to us how and in what sequence the successful solution of the puzzle arises, how it is achieved and even under what circumstances it disappears.

The work of the behaviourists has also many other merits. But it has also very serious defects, not only from the philosophical but also from the purely experimental point of view. The extreme behaviourists deny the existence for man of any subjective world and substitute the conception of "dumb speech" (Watson) for the conception of thought, which, of course, does nothing to settle the question of the peculiarities of human logic and the human mind in comparison with those of animals. Thus the materialism of the behaviourists also

cannot be regarded as firmly based. Nevertheless, in spite of its defects, behaviourism at one time achieved a predominating influence over many of the special sciences cognate to biology and psychology, including psychotechnics, pedagogics, etc.

On the other hand, the ranks of the behaviourists, who never formed a united school of thought, were greatly disrupted by a number of shocks arising in connection with the World War and the world economic crisis. Behaviourism rapidly split into a multitude of separate tendencies, the majority of which concentrated on the study of comparative psychology in its external manifestations, leaving the question of the *internal* mechanism of complex acts of animal behaviour, and in particular the question of the nature of "associative memory" itself, to pure physiologists, and in part to histologists.

At the present time behaviourism is still one of the strongest trends in contemporary psychology. In working on the problem of the relation of the organism to the surrounding world, it employs the numerous resources made available by present-day technique, and there is no doubt that this is one of its strongest sides. We do not desire in any way to underestimate the services rendered by behaviourism in the history of psychology. It decisively put an end to the traditions of subjectivism and anthropomorphism by its declaration that, in dealing with the animal mind, only those things which can be expressed in objective terms should be recognized as real. The character of the reaction of the animals and the velocity and sequence of their movements in response to stimuli—these are the criteria, along with the analysis of statistical data, that are decisive

for an estimate of the animal mind at various stages of development.

Inasmuch as behaviourism deals with the association of movements and not only with the association of ideas, it throws more light than any other psychological trend on the problem of the formation of *habits* and on the means of reducing them to the level of automatism (reading, writing, calculation), which considerably enhances its authority in the eyes of teachers and pedologists.

This analytical approach of behaviourism to the multifarious manifestations of life, this cult of figures, is of course closely bound up with the whole structure of American life. Statistics, however, always have limitations; hence the work of the behaviourists does very little towards the necessary elucidation of individuality, if one speaks, not in terms of coefficients, but in terms of knowledge of *personality*. Moreover, the power of behaviourism gradually weakens as one approaches the study of the higher manifestations of mental activity; it throws little light on the phenomena of analysis and synthesis, of contrast and analogy, which arise as complex varieties in the functioning of the cerebral hemispheres.

The behaviourist approach, unfortunately, did not long continue to enjoy credit among the wide circles of natural scientists engaged in the attempt to deepen our knowledge of the science of life. And the behaviourists themselves, who during a decade and a half had published their special journal and comprehensive series of monographs, lowered their flag and stopped publication without attempting to establish a united platform.

During recent years the behaviourists have not only become divided up into numerous camps and groups, but some of them, such as Lashley and others, have evinced a clear inclination to return to the fold of the old subjective psychology which they previously refused to recognize at all. Thereby they cleared the way for the appearance of new conceptions of behaviour in their opponents' camp such as those of Dr. Köhler with his theory of integral images or forms (*Gestalttheorie*), which we shall deal with at the end of our exposition in connection with Pavlov's criticism of these experiments.

MODERN VIEWS ON THE BASIC PROPERTIES OF NERVE TISSUE

In a notable article Pavlov has stated: "It has become the custom for psychologists to begin a textbook on psychology by a preliminary account of our knowledge of the central nervous system and particularly of the cerebral hemispheres."¹ Unfortunately, it frequently does not go further than this, for the psychologists, after outlining the data on the structure of the central nervous system and sometimes adding an account of the teaching of Pavlov himself, afterwards pass on to the description of facts taken from their own introspective material. Such treatment, of course, does not give any real linking up of the physiology of the nervous system with the activity of the cerebral substratum to which human psychology is indebted for its unusual development.²

¹ Pavlov, "Conditioned Reflexes," article in the *Large Medical Encyclopædia* (Russian).

² This is especially characteristic of Koffke's book, *The Basis of Mental Development*, where the entire account of the nervous system occupies literally half a page.

The physiology of the higher centres of the nervous system, in approaching such a complicated and responsible subject as mind, behaves in exactly the contrary way. The modern physiologist takes into account the anatomy and histology of the brain, beginning with its lower regions, along with the developmental history of the nervous system, both in lower animals and in the embryonic stages. The physiologist does not reject recourse also, if necessary for his analysis, to the material of comparative psychology (zoo-psychology) and sometimes even to phenomena of the subjective world (for instance, the well-known theory of the emotions of the psychologists James and Lange). But in so doing physiology never abandons its own characteristics. Hence one thing is absolutely obligatory for us: beginning with the simplest manifestations of activity in an elementary nerve cell of one of the annelids, and right up to the study of the highest manifestations of nervous activity in the primates, we must adhere strictly to a single basic materialistic principle, a single uniform terminology, and be consistently materialistic from start to finish.

Hence the basic principle for contemporary physiological research is the principle of the objective existence, *i.e.* the reality, of the external world surrounding us. The sense organs of animals also correctly reflect the external world. The science of nervous physiology employs such special conceptions as those of excitation, conduction, extinction, inhibition, irradiation, induction, inertia, lability, etc. Some of them belong to so-called general physiology; they are characteristic not only of animals but to some extent of plants as well.

Others are the subject of research of specialists on the physiology of the peripheral nervous system. Others again apply only to the central nervous system, while a fourth group is characteristic only of the activity of the highest regions of the brain, viz. the cerebral hemispheres.

What unites all these categories is the concept of reflex action. Pavlov says:

“The idea of reflex action as a special elementary function of the nervous system is an old and established truism of physiology. It is the reaction of the organism to the external world, effected through the nervous system, by which an external stimulus is transformed into a nervous process and transmitted along a circuitous route . . . until, reaching one or another organ, it excites its activity. This reaction is specific and constant.”¹

The specificity of the reaction is based, of course, on the subtle specialization of the peripheral receptor apparatus and of the connections within the central nervous system. The constant and stereotyped character of the basic reactions of the organism that are carried out by means of the nervous system has been verified in thousands of experiments.

Until recently, physiologists, including Sechenov, were concerned with simple isolated reflexes, in particular with reflexes in which the initiating action is stimulation of the surface of the skin (over a particular area) and the end effect is the activity of a muscle or group of muscles (also absolutely definite and calculable). Frogs were usually employed as the subject of experiment. Recently, however,

¹ Pavlov, *Lectures on Conditioned Reflexes*, p. 83, English edition, 1928.

physiologists have turned their attention to the more complex aspects of the activity of the neuromuscular apparatus, and for this purpose have more and more frequently begun to have recourse to experiments on the higher animals, particularly mammals, after removal only of the highest parts of the central nervous system.

Such experiments were first performed by the famous physiologist Goltz (1881-92) and were worked out in detail by Sherrington. If the parts of the brain of a cat above the mid-brain are extirpated in the way described by Sherrington, then after some hours (Fig. 2), when the animal has recovered from narcosis, it will be found to be in a state of "decerebrate rigidity." All four extremities are stretched out like sticks. This position depends on the tense condition of the extensor muscles of all joints of the extremities (so-called *extensor tonus*). Suppose an attempt is made to put the animal in its ordinary posture, to put it on its feet. It will be found that it is still able to stand, *i.e.* it can maintain the simplest posture characteristic of all quadrupeds.

This extensor tonus is of very great interest. It is constantly to be observed in the everyday life of the healthy animal. Thanks to it, the very important act of standing becomes possible, both in quadrupeds and in man; thanks to it, the animal can adopt its basic position prior to the act of movement in space. This phenomenon of tonus described by Sherrington is also very important for the subsequent course of our analysis; in this particular case we have as it were an average position of the muscles (extensor) and we can attempt to alter it, by increasing or decreasing their tonus. Attempt now to straighten

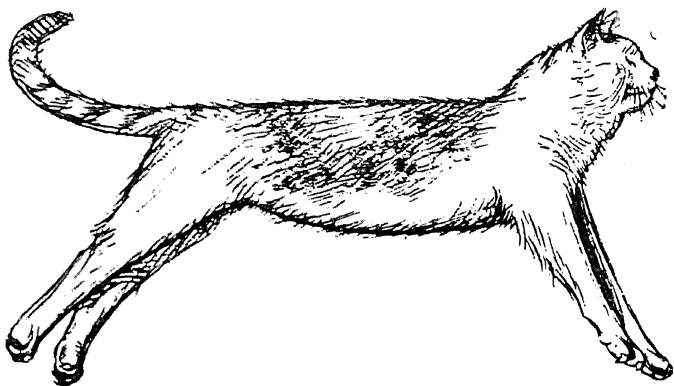


FIG. 2. A suspended decerebrate cat

(From Winton and Bayliss' *Human Physiology*, Fig. 166, on page 456, by permission of Messrs. J. & A. Churchill)

out one of the extremities still more than in the state already resulting from the operation. Considerable resistance will be experienced, but on being forcibly stretched it will remain in the new position given it. Attempt to bend it at the joints, it will again preserve the position given it.

Hence, as a result of the operation, the entire musculature has been put into a remarkable state of plasticity. The animal, as it were, becomes petrified in the posture given it. This plasticity is an important property of the motor mechanism enabling the animal to maintain, without additional exertion, any posture adopted. It is a remarkable means of regulating posture that, of course, functions not only in our experiment but also under normal conditions. It is, moreover, the result of a special reflex, the characteristic feature of which is that in this case the initial excitation consists of a definite degree of tension of the muscle itself. Hence the muscle acts here as a receptor organ. The end effect is the new activity of the muscle—its contraction or relaxation. In this last part the muscle acts as the effector organ, *i.e.* it acts as it normally does.

The reflex action of muscle on muscle is termed a proprioceptive reflex and is carried out as in all reflexes with the participation of definite centres in the spinal cord. That the stimulation proceeding from the muscle is of supreme importance here can be proved firstly by removal of the skin, and, secondly, by the fact that after severance of the posterior roots of the spinal cord, all "tonus" of the muscles of the extremity disappears.

The degree of muscle tonus and muscular movement depends on the strength of the nervous process

taking place in the nerve cells of the *anterior horns* of the spinal cord. The greater the stimulation of these cells, the stronger is the tonus of the contracted muscle.

We must now briefly acquaint ourselves with the mechanism of action of antagonistic muscles. The successes obtained in this field are also primarily due to Sherrington. It is found that stimulation of a cerebral centre controlling flexion produces at the same time a state of inhibition of the centre controlling the action of the extensor muscles of the joints concerned. To verify this phenomenon it is only necessary to cause the extensors to contract, when it will be observed that the flexor muscles are put into a state of relaxation.

Thanks to these experiments, our knowledge of the mechanism of reflex action has become much more complete. From what has been said above it is clear that there exist, not only simple reflexes proceeding according to the scheme "excitation-response," but also double-acting or reciprocal reflexes. The excitation of centripetal fibres, therefore, on reaching the central nervous system, can produce simultaneously two effects, one positive, the other negative or inhibitory.

Moreover, since nearly all activity of the musculature consists in the alternating flexion and extension of the extremities at the joints, the above-described fact of reciprocal excitation and inhibition by means of reflex action acquires almost universal significance. All interfering movements are inhibited as soon as they become unnecessary.

This rule holds good not merely for one particular joint but for all joints; hence, thanks to the pro-

prioceptive reflexes, plus reciprocal action, a firm base is provided for the general co-ordination of the movements of the entire body.

It is of interest to note that when, for instance, the knee extensor has become relaxed as a result of "inhibition," hardly has the stimulus ceased before the extensor tonus not only returns to its previous state but even goes beyond it, that is to say the extremity is more firmly extended at the knee than it was before.

The longer the extensor remains in a state of inhibition, the stronger is the succeeding "outburst" of excitation. This phenomenon has received the name of *nervous induction*. In the case mentioned it indicates the presence of *consecutive excitation* of the nerve centres. What is the physiological meaning of the above-described phenomena?

Inhibition of the antagonistic muscles, as noted above, removes any hindrance to the movement of the organ in the direction required. The subsequent nervous induction facilitates the restoration of the previous conditions, *i.e.* it *prepares* for the movement of the organ in the opposite direction, creating such conditions that the whole series of motor acts can afterwards begin again from the beginning.

Just such a succession of flexions and extensions of the big and little joints occurs in most of our movements, beginning with walking and ending with the highly complicated forms of so-called working movements in man (Sechenov).

Let us briefly enumerate the conclusions following from the study of Sherrington's live "decerebrate preparations," *i.e.* animals deprived of the highest centres of the central nervous system. These conclusions are extremely important for an apprecia-

tion of Pavlov's discoveries concerning the higher functions of the brain.

(1) Motor organs (muscles) undoubtedly function as receptor organs, and hence serve in a dual way as the principal factors in movement.

(2) In the mechanism of complex muscular movements a very important part is taken by the phenomenon of central inhibition discovered by Sechenov, thanks to which a strict co-ordination and sequence in time is imparted to the functioning of the various groups of muscles.

(3) The phenomena described above constitute the basis for the formation of chains of motor reflexes and explain the mechanism of the more complex muscular acts comprised in walking and other *natural* movements of the body.

THE DISTRIBUTION OF NERVE CENTRES IN THE BRAIN AND THEIR MUTUAL RELATIONS

The centres controlling movement are strictly localized in definite parts of the brain. In different groups of vertebrates and even among separate species of a single class, the brain exhibits marked diversity both in form (Fig. 3) and in the distribution of its functions.

The process of development of the brain can be presented diagrammatically by starting from the three hollow swellings or "cerebral vesicles" constituting the anterior end of the so-called neural canal of the embryo. In the lower vertebrates (fishes, amphibians), chief importance attaches to the middle and posterior parts of the brain, *i.e.* to the products of the corresponding cerebral vesicles; in the higher animals (birds, mammals and man) it is the anterior

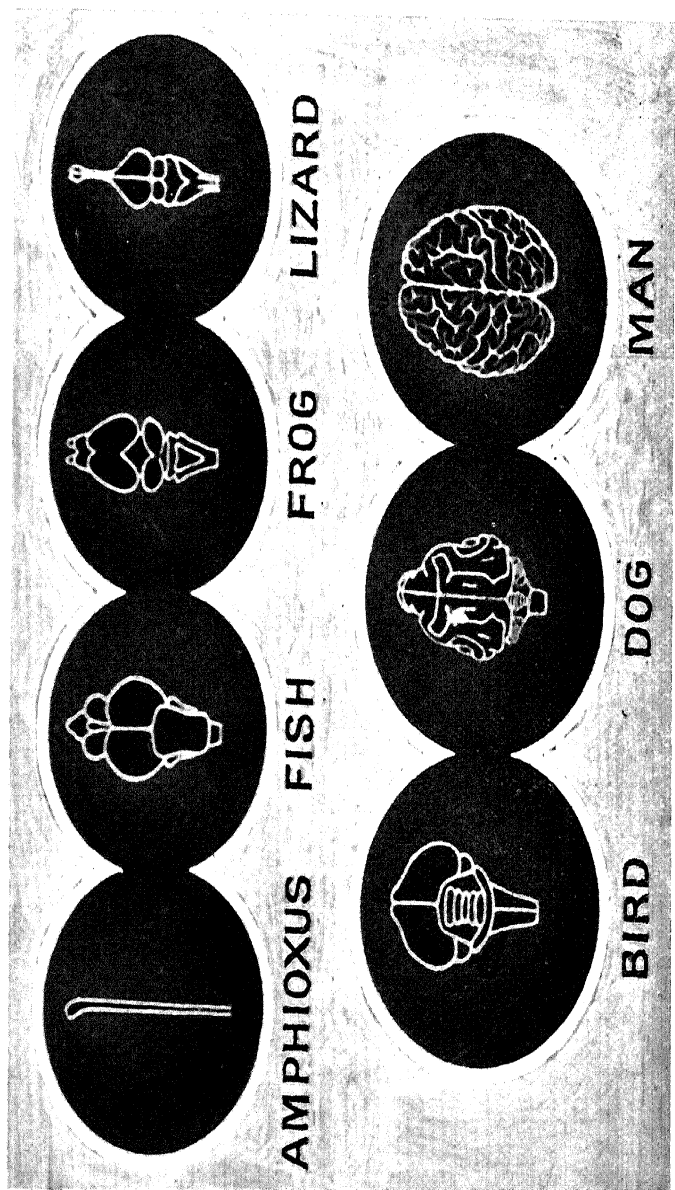


FIG. 3. Diagram of the development of the brain in vertebrates (viewed from above). From the scientific film, "The Nervous System," directed by Galkin

portion of the brain (arising from the anterior cerebral vesicle) that attains particular development.

In different species of animals, the homologous parts of the brain may exhibit not merely different degrees of development, but also different degrees of participation in regulating the work of the whole organism, as can be best determined by the method of *extirpation* of the cerebral hemispheres (Flourens, Munk) or by stimulating the appropriate regions by an electric current (Fritsch and Hitzig).

The anterior end of the neural tube of the embryo undergoes extraordinary changes during development, becoming flexed at various points along its length and swollen in some parts and contracted in others.

All these changes finally lead to the fore-brain (the so-called prosencephalon) in man (and also in the majority of mammals) coming to exceed all the remaining portions both in weight and volume. In its turn it becomes divided into two unequal parts, of which further mention is made below.

The mid-brain in mammals (the mesencephalon), on the other hand, contracts during the course of development of the embryo to relatively small dimensions. It gives rise to the so-called corpora quadrigemina and the pedunculi cerebri. Finally the posterior cerebral vesicle (the myelencephalon) is the origin of the substance of the cerebellum and the pons Varolii and the medulla oblongata.

As regards the hind-brain (and particularly the cerebellum), in spite of its anatomically isolated position and its considerable development in almost all classes of vertebrates (except amphibians), the functions of this organ still remain little known if not completely unknown, although attention has

long been directed to it and it has been the subject of many researches (Luciani).

Apparently, the cerebellum is closely connected with the function of maintaining equilibrium, at any rate the destruction of the cerebellum is accompanied by symptoms similar to those observed in animals after destruction of the receptor apparatus of equilibrium (the so-called semi-circular canals of the temporal bone). Orbeli¹ regards the cerebellum as an adjunct of the cerebral cortex in inhibiting "old" obsolete forms of activity of the muscles and in ensuring a correct distribution of their tonus.

We owe to the Dutch physiologist Magnus and his pupils our knowledge of the role of the mid-brain, or more exactly the corpora quadrigemina. By becoming acquainted with the physiology of the latter we at the same time considerably strengthen and extend our knowledge of the mechanism of reflex actions and in particular of so-called complex or chain reflexes. The anatomical course of the nerve paths as depicted in the diagram (Fig. 4), shows that the superior pair of lobes forming the corpora quadrigemina of a cat are closely connected with the function of light perception, while the inferior pair are closely connected with the functions of the ear² and also with the vocal apparatus. Moreover, the corpora quadrigemina are connected with the entire musculature of the body by special paths, the roots of which (the nerve-cell bodies) are contained in the substance of the corpora quadrigemina themselves. Consequently, as regards its position

¹ Orbeli, *Lectures on the Physiology of the Nervous System*, 1935 (Russian).

² Both as regards reception of sounds and its equilibrating functions.

and neural connections, the mid-brain (mainly the corpora quadrigemina) is the basic regulator of the complex movements involved in locomotion.

It is well known that if a cat is thrown out of a window it hardly ever receives injuries but always

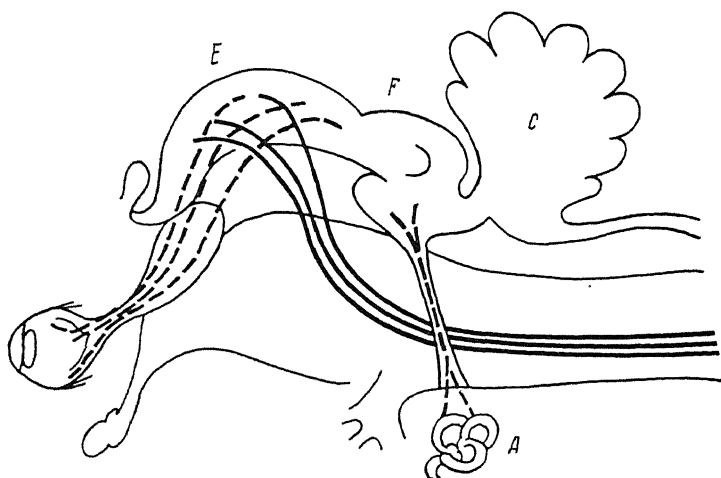


FIG. 4

Diagram of nerve connections in the corpora quadrigemina—*i.e.* in the part of the brain which regulates the complex motions of the bodies of animals.

O—eye; A—inner ear; E—superior lobes of the corpora quadrigemina; F—inferior lobes of the corpora quadrigemina; - - - - - sensory paths; ——— motor paths.

falls on its feet. Very often after such a fall it continues walking as if nothing had happened. Falling in the case of the cat is always transformed as it were into a jump.

What is the basis of this property or faculty, which is undoubtedly of great use to animals accustomed to living in trees and thus continually exposed to the need to jump and the possibility of falling? What part of the brain functions in this “natural

acrobaticism"? For this phenomenon, of course, simple, isolated reflexes do not suffice. We encounter here the mechanism of *chain reflexes*, in which all the parts are reciprocally connected.

In this particular case the chain begins with stimulation of the receptor apparatus of the labyrinth of the ear, the canals of which (three on each side) are so related to one another that any movement of the head causes a displacement of the fluid contained in them. This movement of the fluid stimulates the nerve endings distributed over the walls of the canals. The principle of the mechanism is much the same as that of an ordinary water-level¹ with the apparatus attached to it for measuring inclination.

The signals from the labyrinth reach the medulla oblongata and immediately evoke by reflex action an alteration in the tonus of the cervical muscles, as can be traced in experiments with cats operated on by Magnus' method.

Without Sherrington's conception of muscle tonus, without a knowledge of the constant contractibility of muscles, we should be entirely incapable of analysing this complex question. In studying acrobatic actions exhibited by animals, as in the case of the falling cat, one must note the extremely important part played by the tonus of the cervical muscles. Magnus has shown that for a definite angle of inclination of the head to one side or the other there corresponds an absolutely definite degree of tonus (contraction) of the cervical muscles. This contraction is produced to an extent which permits

¹ Such water-levels, attached to two surfaces at right angles to one another, are used in ships and aeroplanes for measuring the extent of departure from the horizontal.

the head to be brought back to the normal position. The change takes place thanks to reflex action of the cervical muscles, initiated by impulses originating in the labyrinth. If at the moment of its fall an instantaneous photograph is taken of the cat, it will be seen that the animal has a rather strange appearance owing to the unnatural (twisted) position of the head. Immediately afterwards a new regulatory mechanism contained in the corpora quadrigemina comes into play; a sequence of nervous impulses of definite strength proceeds from the muscles that have already been stimulated to contract. Reflex action brings about a contraction of the muscles controlling the position of the anterior portions of the trunk, and this leads to the latter being brought into normal relation to the surface of the earth.

The chain of reflexes, therefore, contains not one but two links.¹ The second link is followed by a third, viz. the contracted muscles of the anterior part of the body (in particular of the fore limbs) in their turn despatch impulses to their reflex centre, thanks to which a reflex action is exerted through the spinal cord on the muscles of the posterior part of the body. The final result is that the cat rights itself while still in process of falling, and thus has all four legs in just the position and with just the degree of tension necessary to prevent it receiving any injury on landing.

We mentioned above that in Sherrington's preparations, *i.e.* under conditions where the integrity of the corpora quadrigemina is not preserved, animals

¹ These links are: (a) labyrinth—medulla oblongata—cervical muscles; (b) cervical muscles—corpora quadrigemina—muscles of the fore limbs.

(cats) are incapable of executing any complex movements. We know now that if the integrity of the corpora quadrigemina and *thalamus* is preserved, even the most difficult actions, *e.g.* acrobatic movements, are carried out by such animals with remarkable precision, thanks to the still higher disposition of the quadrigeminal brain mechanism. On destruction of the corpora quadrigemina, of course, all these functions disappear. Hence it is the mid-brain in animals which is the chief regulator of their movements.

The fore-brain (prosencephalon) of mammals has the most complicated structure of all. It is divided into the telencephalon and the diencephalon. The latter includes the *optic thalamus*. The thalamus contains a multitude of nerve cells; it is here that the afferent path leading from the surface of the body to the cerebral hemispheres relays. The diencephalon regulates metabolism, growth and the secretion of certain glands. These centres also perform an important function in regulating movements requiring the highly complex participation of the higher centres of the central nervous system. What are these movements?

Sufficient has already been said of walking, jumping and acrobatic movements in animals. But, besides these complex movements, there are a number of others, including, for instance, the act of eating, the sexual act and also all those complex movements which are displayed by animals during struggle or pursuit of prey. These latter movements (see Figs. 5*a* and 5*b*) are distinguished from those described above by still greater complexity; apparently, the centres included in the thalamus are concerned in their regulation.

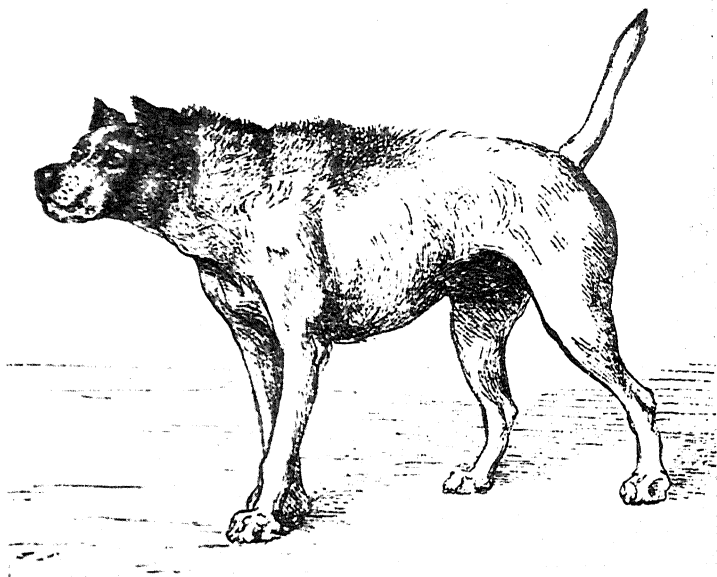


FIG. 5a. The expression of emotions in animals, according to Charles Darwin
A dog's expression of anger

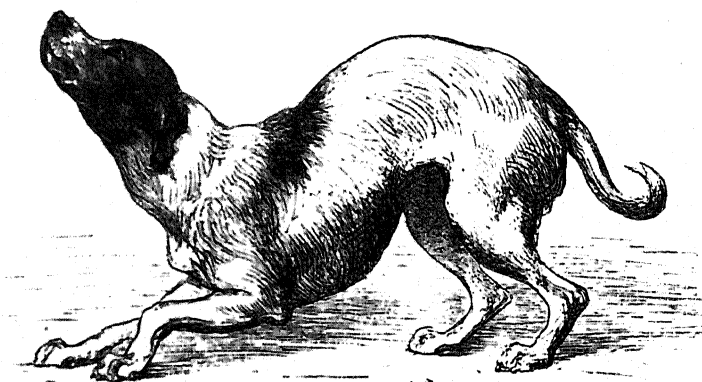


FIG. 5b. The same. The same dog expresses love

This is in accordance with the fact of the extremely close nervous connection between the thalamus and the higher sense organs. The term optic thalami itself indicates their close connection with vision. In addition, clinical observations have shown that, in cases of injury to the thalamus on either side, the patient exhibits on that side complete absence of movements of the facial muscles. This lack is demonstrated most strikingly in those cases where such movements would naturally be expected. Thus, for instance, on crying, the corners of the mouth are not depressed as would naturally be expected, nor is joy accompanied by the curving of the lips in a smile. In short, under such conditions, the human countenance loses all its customary expressiveness. In such features even the most attentive observation fails to reveal the expression of any emotion.

A dog in which the frontal part of the brain has been excised, while leaving the optic thalami intact, will make a characteristic *grimace* if some bitter substance (*e.g.* quinine) is put in its mouth. If, however, the thalami are injured, such a grimace will never be exhibited. At the same time the familiar acts of growling and barking also disappear, that is to say there is a disappearance of all those reflexes which are characteristic of the organism putting itself in a state of readiness for defence or attack and which constitute an important "weapon" when it is necessary to threaten or intimidate an enemy. Finally, there disappears also the motor reflex of the male to the presence of the bitch—in short, all those complex (chain) reflex actions which are fundamental and inborn in all animals and which intimately determine the behaviour of the animal

amid the dangers of the external world where it is compelled to fight for its "right to live."

Hence, the complex mechanism that controls and regulates the main features of the basic, inborn forms of animal behaviour culminates in the optic thalami. The part played by these structures is very large. As long as they are intact, the animal retains all the highly complex actions of locomotion and "expression," and likewise retains all the reactions connected with "courtship" that make their appearance periodically at definite stages of the animal's life.¹

In the higher animals, however, the optic thalami do not represent the highest structure of the central nervous system, which extends far above them, forming the terminal brain (the so-called *telencephalon* or cerebral hemispheres). Thirty years ago a textbook of physiology would conclude at this point its objective description of the activity of the latter extremely important region. The physiologist would give place to the psychologist, who approaches the subject of investigation from an absolutely different and purely subjective standpoint. Now, however, a change is taking place. It was no other than Pavlov himself who broke this "conspiracy of silence" and who introduced a rich physiological content into the sphere of the study of the life and activity of the cerebral hemispheres under the general title of the theory of *higher nervous activity*.

¹ In the latter case an important function is fulfilled by the activity of certain glands of internal secretion, in particular the sex glands, which secrete their products, not only externally (sperm, egg), but also directly into the blood (sex hormones), in this way exciting the activity of various parts of the nervous system.

Chapter II

PAVLOV'S THEORY OF CONDITIONED AND UNCONDITIONED REFLEXES

THE PHYSIOLOGICAL CHARACTERISTICS OF INSTINCTIVE ACTIONS AS UNCONDITIONED REFLEXES, AND THEIR CLASSIFICATION

ANY number of examples can be given of the complex nervous co-ordinations which we call reflex action and which in common speech are often referred to as "*unconsciously purposive*" acts.

Thus, for instance, secretion of sweat in the higher animals on raising the temperature of the environment is evoked reflexly; the appearance of shivering on sharply lowering the temperature of the surroundings is likewise the result of reflex action. The stoppage of breathing which occurs when vapours of substances harmful to the lungs come into contact with the mucous membrane of the nose is determined by reflex action, as also the similar stoppage of breathing on complete immersion of the organism in a liquid medium. In very many cases the acceleration or retardation of the contractions of the heart is the effect of reflex action. It is a reflex mechanism also that is called into play when large losses of blood occur, and counteracts the large fall of blood pressure which would occur in the absence of any such mechanism. The occurrence of coughing when even insignificant amounts of a foreign

body get into the throat, or of sneezing when such a body enters the nasal cavity; the phenomena of hiccoughing and vomiting—all these are essentially reflex actions from beginning to end. The appearance of various digestive fluids depending on the nature of the substance to be digested, as also the accurate dosage of the digestive enzymes, is the final result of a whole series of reflexes, and similarly also the peristaltic movements of the stomach and intestines. Finally, it is only thanks to reflex adaptations that accurate correspondence between the component factors of the complex act of birth becomes possible.

The above remarks serve to make clear the tremendous role of so-called complex inborn coordinations or chain reflexes in the general economy of a functioning organism, *i.e.* one that adapts itself to external conditions. These actions, being for the most part pre-formed and ready to make their appearance from the first moment of the independent life of the animal, often prove to be at the height of their perfection at their very first application. They could not be better adapted in relation to the external stimuli which the organism seeks or which it must avoid. They preserve their integrity until the animal ceases to exist or until the onset of serious illness. During illness, too, reflexes, the existence of which was unsuspected, sometimes make their appearance. Thus, for instance, a dog suffering from tapeworm will search out and devour the plant known as wormwood.

These complex reflexes, in spite of all their external diversity, can be embraced in the general term of *instincts*. Hence, an instinct is an effect and

not an internal impulse as was believed by the Stoics, who first introduced the word.

In our era, under the influence of Pavlov, physiology designates as instinctive movements all those complex inborn co-ordinations or reflexes which always proceed strictly in accordance with a natural law, although they sometimes possess a very complicated chain character. In the first place, such reflexes guarantee the equilibration of the organism with its environment, sometimes over a very considerable extent. The co-ordinations corresponding to them are closely dependent on the anatomical structure of more lowly situated portions of the central nervous system, viz. the so-called basal ganglia, and on changes in the internal chemistry of the organism, *i.e.* on changes in the state of the so-called organs of internal secretion.

Instincts can be divided into two basic biological groups. The first group consists of sex reflexes in the wide sense, *i.e.* those serving for the preservation of the species. The second group contains reflexes serving to safeguard the existence of the individual. The latter, in their turn, are divided into: (a) *food reflexes*, *i.e.* those connected in one way or another with the act of assimilating food, and (b) *defence reflexes* in the narrower sense of the word, *i.e.* those serving to maintain the inviolability of the organism.

All these diverse activities, inborn and highly perfected, are termed by I. P. Pavlov *unconditioned reflexes*. Let us take, for instance, the well-known activity of beavers, which construct long and firm dams in order to stem the movement of the rapid Siberian rivers, thus raising the level of the water

sometimes to a considerable degree, and shutting off the entrance to their dwellings. They act in this way even in captivity, when their security is not threatened in any way. As observation has shown, they employ in these complex operations only their tenacious claws and strong teeth.

Let us turn to the migratory birds, which carry out journeys of thousands of miles with the exactitude of an aviator equipped with all the necessary instruments for aero-navigation. In the course of a single year, such a small bird as the sandpiper covers, twice over, a distance almost equivalent to a complete terrestrial meridian. Even the cuckoo, which makes its migratory flights in solitude, trusts exclusively to its internal "instinct," which with the accuracy of a compass guides it to the very spot where it was born.

As we shall see later, however, this instinct, although inborn, exhibits extraordinary individual variations and is subject to natural selection.

In the insect world we may recall the case of ants, which construct enormous dwellings, equivalent in proportion to their size to a large American skyscraper. Ants carry on elaborate fruit-growing operations as well as regular stock-breeding, and construct capacious stores for their winter reserves. Bees construct with mathematical accuracy their remarkable, hexagonal-celled combs which they fill with honey. At the same time, we find in the insect world—this world of the "Classic" exhibition of instincts—a whole series of transitional stages in building construction, beginning from the very imperfect cells of the humble bee (*Bombus*), which are crudely stuck together with saliva. In general,

very great caution has to be exercised in studying these inborn but purposive acts which are termed instincts. Besides research in the field of complex, individually acquired nervous reactions, Pavlov's laboratory has carried out and continues to carry out observations on certain inborn reactions and instincts.

This, of course, is far from meaning that at the present time we have anything like a full knowledge of the internal mechanism of inborn reflexes or instincts. The view of the physiologist in this respect is much more modest, but also much more definite, than the claims put forward by zoo-psychologists in the past.

We consider that a given instinct has been scientifically studied only if we are able: (1) to determine the external and internal (chemical) stimuli which arouse the action of this reflex. This holds good particularly for reflexes that manifest themselves periodically; (2) to determine the place occupied by the inborn reflex under investigation in the general "hierarchy" of reflexes, *i.e.* to appraise its relative strength at the given time. Other reflexes (*e.g.* the defensive "sexual" reflex) that have been more completely studied serve here as a measure; (3) to demonstrate what parts of the reflex really are inborn and what phenomena have been accumulated on this basis in the course of the life of the individual; the latter, as we shall see later, is not always easy to determine. Incidentally, it may be remarked that it is just its weakness in separating the inborn from the acquired parts of instincts, that has caused zoo-psychology to remain hitherto very much on the level of Plutarch's fables.

It fell to Pavlov to rescue it from this confused state, and we shall proceed now to a description of his experiments.

PAVLOV'S "BASIC PRINCIPLE" OF THE MUTUAL
RELATIONS OF CONDITIONED AND UNCONDITIONED
REFLEXES

Unconditioned reflexes form the foundation on which is gradually accumulated a superstructure of reflex reactions of very diverse composition. I. P. Pavlov has given the latter the name of "conditioned" reflexes.

Thus, for example, the contraction of the circular muscle of the eyelids on the approach of a sharp object to the surface of the pupil, all complex muscular acts which go to make up self-defence and attack in animals, all the reactions preceding the moment of onset of actual stimulation and giving warning of it, are conditioned reflexes operating in the time dimension. But they can just as well be called temporary reflexes.

They are "conditioned" because they are distinguished from the previously mentioned fundamental (inborn) reflexes or instincts, by their extreme instability. The conditioned reflex is a temporary connection which arises only in the course of individual life. As a rule, it is established with a certain amount of difficulty, and rapidly disappears when the conditions vanish that have brought it into being. There is a distinction between conditioned and unconditioned reflexes further in the fact that the arc of the unconditioned reflex passes through the lower centres of the nervous system, as already

described, while the arc of the conditioned reflex passes through the cortex of the cerebral hemispheres. This is why conditioned reflexes are "cerebral reflexes" in precisely the sense in which their discovery was foreseen by I. M. Sechenov.

There is no fundamental difference between these two varieties of reflexes; in both of them the starting-point consists of stimulation of peripheral nerve endings. In both of them there is involved a neurone, or a number of neurones, included in the central nervous system. Finally, in both conditioned and unconditioned reflexes, a definite external motor or secretory effect is produced. We are not concerned for the moment with reactions which do not give either of these effects, *i.e.* which are not expressed externally at all. Such reactions are called negative or inhibitory.

Everything that is not immediately reflected externally in the form of action is reflected later on after a definite interval of time. The delayed reflex influences other manifestations of the higher nervous activity and in this way makes its presence known. Hence in the last resort all phenomena occurring in the nervous system and its higher centres become the subject of our discussion and objective analysis.

Until recently it was considered that the food reflex is a phenomenon which begins from the moment when food comes into contact with the mouth. In regard to the defence reflex, it was thought that it takes place after a blow has been struck. As for those cases where an animal reacts to the approach of food, it was considered that this was no reflex but some special act indicating passionate desire for food, "impatience" on the part of the

dog, etc. Pavlov with much good humour recalls the fact that at the beginning of his work on salivary conditioned reflexes he had a dispute with one of his colleagues, who advocated this point of view, *i.e.* this colleague defended the special position of "psychical" salivary secretion among the physiological phenomena connected with the salivary gland. Pavlov says:

"Among my collaborators was a young doctor with an active mind capable of appreciating the joys and triumphs of investigation. Great was my astonishment when this loyal friend of science became profoundly disturbed on hearing of our plans to investigate the psychical activity of the dog in that same laboratory and by the same means which we had been using for the solution of physiological questions. All of our arguments were ineffective; he prophesied and hoped for only failure. The cause of this, as far as we could understand, was his idea that the psychical life of man and of the higher animals was so individual and exalted that it not only did not lend itself to investigation, but would even be sullied by our crude physiological methods.

In dealing with the highest vital phenomena, the fact must not be overlooked that a genuine systematic application of natural science to the last limits of life will not be able to avoid misconception and opposition from those who have long been accustomed to regard these phenomena from another point of view, and are convinced that this point of view is the only legitimate one in the circumstances."¹

Thus, from the outset Pavlov put before his

¹ Pavlov, *Lectures on Conditioned Reflexes*, English edition, 1928, pp. 81-2.

co-workers a question fairly simple in itself but one that demands considerable thought and that is still far from having been properly appreciated by everyone, viz.: Is the sight of food a *necessary* adjunct of the food?

Pavlov succeeded in showing that the two phenomena of the reaction to the sight of food and the reaction to the act of eating can be separated from one another, and by a very simple means at that. If an animal is shown food, *e.g.* meat or biscuit powder, but is not given any to eat, then the sight of the food gradually loses its stimulating property in respect of salivary secretion. (B. P. Babkin's experiment.)

The physiology of conditioned reflexes began, properly speaking, with this fact, viz. the breaking up of a very simple universally known "association" and not with the establishment of complex laws of complicated motor habits such as formed the starting-point for the behaviourists.

Pavlov then turned with his questions to the psychologists. He asked how they interpreted the phenomenon from their point of view. Their answer was as follows: if the dog is not given food it becomes disillusioned; it has no desire to waste a single drop of saliva on such a hopeless business where there is no advantage to be gained. Pavlov, however, continued the experiment and showed that if a certain time interval is allowed to elapse, for instance an hour, and the dog is then again shown food, the conditioned reflex is restored. To this, the psychologists are able to reply: the disillusionment passes off and the dog once more believes that this time he will receive food. But is not this "explanation" a sheer fiction? asks Pavlov.

Are we not ascribing to the brain of the dog our own experiences, such, for instance, as we undergo when we expect to see a performance and are disappointed because it is delayed? Is this subjective standpoint suitable under conditions where the question at issue concerns the "modest" work of the salivary gland, and is it not better to renounce such a standpoint and to put the question on a purely physiological plane? An artful question, to which the psychologist answers only with great hesitation, for if it is admitted that there exists even a single psychical act of the animal that can be fully explained in a purely physiological way, then the whole long-standing edifice of zoo-psychology will collapse in ruins.

Let us add here one more fact which is difficult to treat on psychological lines, the explanation of which will be given below: if, as described above, we have provoked the dog's "disillusionment" as to the possibility of receiving food, it is sufficient merely to clap one's hands loudly, or in general to bring any strong external stimulus to bear, for the dog to return to its former state, *i.e.* again to begin to secrete saliva. From the physiological point of view, only one conclusion can be drawn from this, *viz. the sight of food is not an essential property of the food*, that is to say it does not form an indispensable constituent of eating; it is obvious that it is possible to find food without seeing it. The essential property of food lies in its *taste* alone. But, while the sight of food is not an essential property of it, by means of extinguishing some reflexes and strengthening others it is possible to cause the "essential" and "un-essential" properties to change places at will. This

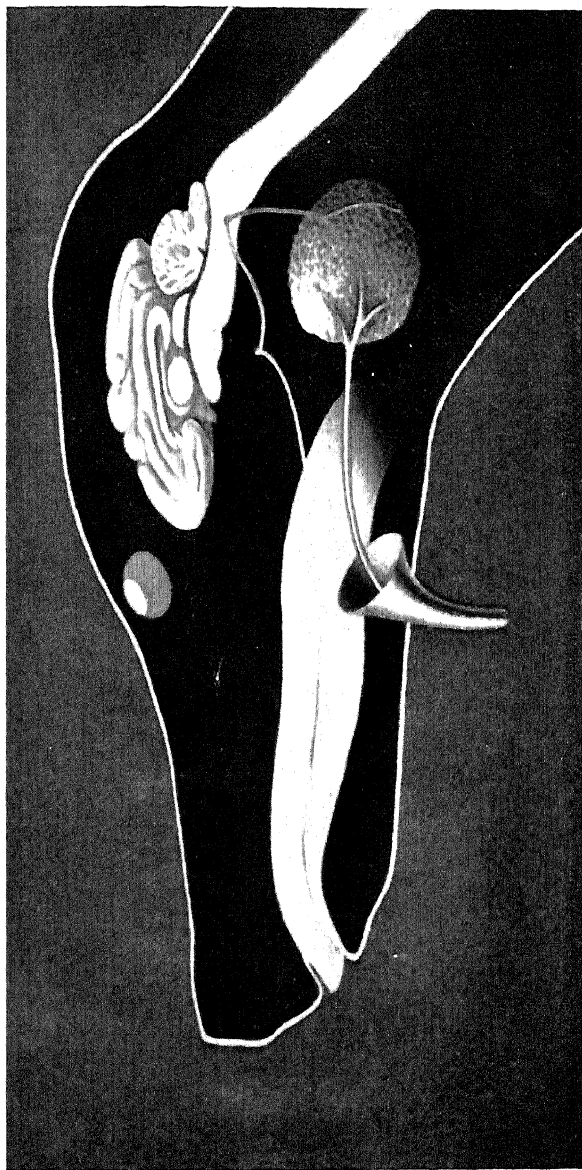


FIG. 6. Diagram of the path of the inborn unconditioned reflexes from the mouth cavity to the salivary gland in a dog. The figure shows that the result of excitation of the wet tongue is transmitted along the centripetal nerve to a centre in the medulla oblongata, whence impulses are directed to the salivary gland. From the scientific film, "The Nervous System," directed by Galkin

indeed was the object of numerous further experiments performed in Pavlov's laboratory.

From the fact just described, still another conclusion can be drawn: conditioned reflexes are formed mainly, almost exclusively, on the basis of unconditioned reflexes or instincts, although sometimes another older conditioned reflex may serve to reinforce them.

In the majority of cases, the matter proceeds in the following way: If some stimulus acts on the mucous membrane (*e.g.* if a drop of acid is applied to the tongue), nervous impulses are conducted along the centripetal (afferent) nerve fibres to the medulla oblongata, to the saliva-secreting centre, and there excite the centrifugal (efferent) nerves along which impulses travel to the parotid or submaxillary glands. The latter respond immediately by secreting into the oral cavity a definite quantity of saliva, depending on the quantity of acid put into the mouth, its concentration, etc.—the factors which determine the strength of the stimulus (Fig. 6).

This reflex is inborn and constant. In the case described, its character is clearly defensive (defence of the oral cavity against irritation by acid). If a piece of meat is put in the mouth of a puppy which has not yet begun to eat meat food, saliva will be bound to appear. This is an unconditioned salivary reflex to food. If a completely normal puppy, but one which has hitherto never been given any meat food, is shown a piece of meat as in the experiment of Pavlov's pupil Tsitovich, the puppy will not only not touch the meat, but will frequently turn away from it and even growl (negative reaction). It is

sufficient, however, merely to "reinforce" the exhibition of the food by the act of eating, and subsequently the sight of meat will cause the puppy to turn its head towards the food shown and even to give a considerable secretion of saliva from the duct of the gland (positive motor and secretory reaction).

It is evident that certain changes gradually take place in the nervous system of the animal, so that new connections are established between the organism and the external world. These connections are made through food, are strengthened by food and thereby obtain enormous strength.

— If the cerebral hemispheres of a dog are removed, as was first done by G. Zeleny, the sight of food will never evoke the above-mentioned characteristic reaction either in a puppy or an adult dog. Consequently, the reaction of the dog to the sight of food necessarily involves the participation of the cerebral hemispheres and, in particular, the mediation of nerve elements contained in the cortex. If we weigh up the results of the numerous experiments specially made for this purpose, it is impossible not to arrive at the conclusion that the reaction of the animal to the sight of food is a reflex action similar to the inborn reflexes described above, although differing from the latter in certain essential respects.

— How is this new connection in the brain established?

The light stimulus proceeding from a piece of food of definite form and colour passes along the appropriate centripetal nerves, in this case the optic nerves, to the occipital portion of the cerebral cortex. If at the time there is no sufficiently powerful focus of excitation either in the cerebral hemispheres or

in the subcortical centres, then the above-mentioned excitation in the cortex produced by the light stimulus gradually disappears and is dissipated over the mass of the neighbouring nerve cells without leaving behind any immediate effect. If the animal is fed simultaneously with the stimulation of the eye—and it should be noted that feeding produces a highly complex excitation of many centres in the nervous system, including the “food centre”—then the above-mentioned visual stimulus enters into connection with the centre of food excitation. Such a firm connection is gradually established between the two points of the nervous system that, in the subsequent course of the experiments, it is sufficient to produce stimulation of the eye by the sight of food alone for the part of the food centre that controls the process of salivary secretion to come into operation (Fig. 7).

Hence several conditions are required for the appearance of a new reflex arc corresponding to the newly established connection of the animal with its surroundings. The first condition necessary for the formation of a reflex whose arc passes through centres situated in the cerebral cortex is that the new stimulus should coincide in time once or repeatedly with the action of the old stimulus that always evoked a definite reaction of the animal (in this particular case, the positive food reaction).

All higher nervous activity carried out by means of the cerebral hemispheres, when regarded from the physiological standpoint, is found to consist, in Pavlov's view, of a multitude of conditioned reflexes. This holds good equally for the above-described secretory reflexes and also for muscular reflexes.

At the same time each newly elaborated conditioned reflex represents an extension of the

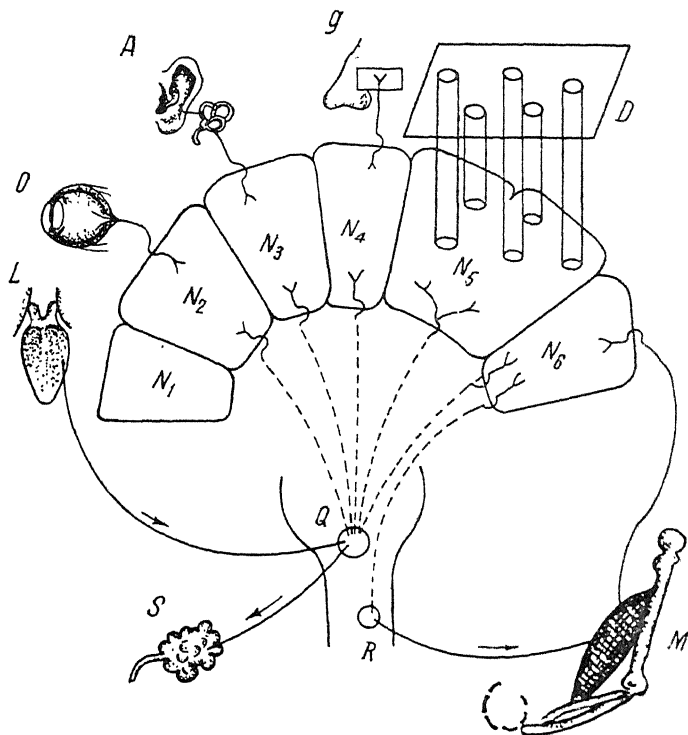


FIG. 7

Diagram of the formation of the conditioned salivary reflex, according to I. P. Pavlov (with certain additions by the author).

A—organ of hearing; *L*—organ of taste; *O*—organ of sight; *G*—organ of smell; *D*—organ of touch and temperature. Executive organs: *S*—salivary gland; *M*—skeletal muscle; *Q*—saliva-secreting centre in the medulla oblongata; *R*—motor centre in the spinal cord. Nos. 1, 2, 3, 4, 5, 6—analysers of different forms of external excitation in the cortex; ——— permanent, innate connections; - - - - - acquired, temporary connections, or conditioned reflexes.

personal (individual) experience of the animal. And vice versa, if the personal experience of the animal

is enlarged, this signifies that the number of its conditioned reflexes has grown.

In studying the physiology of the lower centres of the brain, we became acquainted with certain basic rules of the functioning of the reflex apparatus. We are already aware of the enormous importance of such processes as excitation, inhibition, and partly also induction, and their mutual relations. So far, however, we have not encountered the phenomenon of the coupling of nervous connections such as inevitably arises when conditioned reflexes are formed before our eyes. The nervous connections in all the cases described have always made their appearance before us in a prepared form. It is now possible for us to be present during the birth of *new* connections in the brain.

The cerebral cortex, therefore, is distinguished from other regions of the central nervous system by the fact that it is the seat of the formation or coupling of new, individually established connections between various phenomena of the external world and various aspects of the activity of the organism.

The mechanism of the coupling of new connections is of tremendous service to the higher representatives of the animal world. In the process of the continual struggle for existence it is obvious that the *time* when a reaction begins is throughout a matter of great moment. Every second gained is of enormous significance. It is extremely important for a hungry animal that it should always react to food as soon as it appears in its field of vision, for it is obvious that if it does not do so other animals in the neighbourhood may seize the prey before it, for

which an incessant struggle is always taking place. Consequently, the assertion is fully justified that in the struggle for existence the animal that is successful will be one in which the mechanism of the formation of conditioned reflexes functions best of all. It is true that, as will be shown later on, very much has to be added to this brief assertion.

We shall remark here that the stimuli mentioned, e.g. the sight and smell of food, are called by Pavlov *natural conditioned stimuli*. The connections corresponding to them are elaborated during the very first months of the animal's life. They are established very rapidly. Laboratory work with such natural reflexes is not difficult; everyone who breeds animals has to deal with them. On the other hand, such work does not furnish much material for conclusions owing to these reflexes being limited in number: the stimuli evoking them include the sight and smell of food and partly sounds given out during preparation of food, and that is all.

For the purposes of experiment, it has been found much more expedient to utilize so-called *artificial conditioned stimuli*. In view of the fact that the physical character of an external stimulus selected for the elaboration of a conditioned reflex is completely indifferent from the point of view of the physiologist, as long as it is accompanied by the unconditioned stimulus, i.e. by eating or the introduction of acid into the mouth, the physiological laboratory today can employ any kind of source of physical energy as a stimulus for producing conditioned reflexes.

THE BASIC EXPERIMENT OF THE FORMATION OF
AN ARTIFICIAL CONDITIONED REFLEX

How does one carry out the basic experiment of the formation of a conditioned reflex, or rather, how was the experiment carried out in the period of the early work on the study of higher nervous activity before 1914?

A dog was always selected for the experiment; one not too young and not too old, usually taken from the homeless backyard curs which were easy to obtain. After certain observations, a fistula was made of the duct of the parotid or submaxillary salivary gland, a proceeding which has no adverse effect on the general health of the dog or on the process of digestion. This small operation was performed on the dog in order to use the secretion of saliva as an indicator of one reaction or other. In the mouth of the anæsthetized animal a small swelling is found on the mucous membrane of the inner surface of the cheek at about the level of the second molar. This papilla may have a bright rose or somewhat dusky colour, and on pressure it sometimes secretes a small quantity of transparent saliva. It marks the opening of the duct of the parotid gland and is all that is required for our operation.

A fine flexible probe is gently introduced into the opening of the papilla, and the slightly thickened end of the probe, by cautiously turning it, is passed into the duct to a depth of 5-10 cm. It is now necessary to separate the papilla and duct together with the surrounding tissues from the general mass of the cheek tissue.

When the duct has been separated for a depth of

about 4-5 cm., the papilla of the duct is brought out to the *external* surface of the cheek through a special incision which is made through the whole thickness of the cheek. The incision is made from the inside, and reaches the outside at a place on the cheek which has been previously prepared and closely shaven, so that subsequently it will be suitable for the attachment of a funnel and apparatus for measuring the salivary secretion.

Following this, the edges of the mucous membrane are sewn to the edges of the incision in the cheek, this sewing being carried out with extreme care, using very fine needles and silk thread. The gap left in the mucous membrane of the mouth does not call for such great care in sewing up, but the sutures must be sufficiently strong.

For some time after the operation, the papilla in its new place must be carefully safeguarded against trauma by smearing its surface with vaseline and attaching a light bandage.

After some days, when the opening of the gland has become definitely established in its new place and saliva begins to be secreted normally from its base, just as if it had always appeared on the outside instead of on the inside, the experimenter can remove the stitches and thoroughly clean the edges of the wound, at the same time giving the dog some meat powder to eat so as to ensure better cleaning of the fine canal of the duct. Finally, when the traces of the operation to the cheek have entirely disappeared, a metallic or glass funnel with a bent end, for greater convenience in counting the drops of saliva, can be attached to the dog (Fig. 8).

Let us suppose that our dog, on eating 15 grams of

meat powder slightly moistened with water, secretes twenty drops of fluid saliva from the duct of the parotid gland, the whole process of eating lasting thirty seconds. To start with, let us record this modest result of our research as a measure of the strength of the *inborn*, unconditioned reflex.

Duration of Eating.	Size of Unconditioned Reflex.
30 sec.	20 drops

During all subsequent experiments, these figures at the right-hand side of the protocol will be a measure of the appetite and general well-being of the dog. Only on marked overfeeding or during serious illness should this figure ever fall to zero.

When it is certain that the dog has become accustomed to the procedure of fixing it in the stand and giving it food in doses, it is possible to proceed to experiment with some stimulus, not very powerful but not too weak, *e.g.* the ticking of a metronome. It is essential to verify here whether this stimulus evokes some *special* reaction on the part of the animal, for instance, sharp turning of the head, trembling of the body, etc. Having satisfied oneself that the stimulus is actually indifferent, the exact date and time of the experiment is noted and the new stimulus is set going shortly before it is intended to give the animal food. The experiments are made not more frequently than once in 5-10 minutes, and during the whole day there should not be more than seven or nine repetitions altogether lasting from an hour to an hour and a quarter.

The first time that the metronome is used, of course, we do not obtain a single drop of saliva during its *isolated* action. The motor reaction in this case consists at the most of the dog pricking up its ears. But with each subsequent trial of the metronome, accompanied after thirty seconds of its isolated action by giving food, it will be noticed that the behaviour of the dog becomes more and more active. As soon as the metronome begins to sound, the dog starts to lick its chops, and presently it is found that after the metronome has been going twenty seconds (the so-called latent period) the first, and for the time being the only, drop of saliva falls from the gland. The conditioned reflex is beginning to appear.

The next time the number of drops increases to three, while the latent period decreases to ten seconds. These results can be recorded on the right-hand side of the protocol, as follows:

Time of Beginning of Conditioned Stimulus.	Series No.	Stimulus.	Size of Conditioned Reflex (Drops).	Latent Period.
3.20 P.M.	1	Metronome	0	—
3.28 „	2	„	0	—
3.35 „	3	„	1	20 sec.
3.39 „	4	„	3	10 „

In this way it becomes possible gradually to elaborate conditioned reflexes in the dog to the flashing of an electric lamp, to the appearance of various figures in the animal's field of vision, to the sound of an electric bell, trumpet or telephone, to a rhythmic contact of blunt or sharp objects with the

skin, to warming or cooling of particular portions of the surface of the skin, and so on. By systematically applying such stimuli, it has been found that the stability of the elaborated conditioned reflex, on being repeated a number of times, grows until it reaches a certain constant figure. By establishing firm "standards" of this kind, the physiologist can observe the development of the corresponding cerebral connections and their dependence on various factors, deliberately introduced into the experiment or entering against our will, but which can be fully taken into account, thanks to the method of conditioned reflexes.

The physiologist is now fully acquainted with a considerable part of the complex relation between the organism and its environment, since under laboratory conditions we can connect any external stimulus selected by us with the food or defence reaction of the animal, and thus direct the animal's individual experience to one side or the other, or restrict it.

Do the connections once established in the brain last *for ever*? Experiments with conditioned reflexes (natural and artificial) show that this question must be answered in the *negative*. If the conditioned stimulus is, once or more, not accompanied by the action of the unconditioned stimulus, we see that the corresponding connection at once begins to weaken and finally breaks. It will be recalled that the connections arising in the cerebral hemispheres are temporary. This obligatory extinction of reflexes, if they are not reinforced, is the second basic law of the higher nervous activity of normal animals.

Conditioned reflexes disappear just as easily as

they appear. Nevertheless, they do not disappear accidentally or arbitrarily but under quite definite conditions. Their disappearance has a very clear biological meaning; if the signal begins to signalize incorrectly, *i.e.* if it ceases to be the herald of approaching prey or threatening danger, it ceases to be a signal and becomes a neutral phenomenon.

EXTIRPATION OF PARTS OF THE CEREBRAL CORTEX AND ITS EFFECT ON HIGHER NERVOUS ACTIVITY

Let us pass now to the subject of the *localization* of conditioned reflexes. The seat of localization of acquired experience has long been known. Beginning with the classical work of Malpighi¹ and Goltz in the 'nineties of the last century, it has been possible successfully to perform the operation of removing the entire grey matter of the cerebral hemispheres in a dog, the animal remaining alive for a long period. As a result of this operation, Goltz succeeded in observing a number of interesting facts concerning normal and pathological symptoms. Such an animal can move about quite normally; it can run, take nourishment, perform its natural functions, and it is even capable of mating and producing offspring. At the same time, in spite of this wide circle of activities, it was found that Goltz's dog could die of hunger in the midst of abundant food, or could die of thirst in spite of water being available, and if let loose in the street it would certainly perish under the wheels of the first oncoming vehicle. Such a dog does not recognize

¹ As early as 1822 Flourens had observed the behaviour of pigeons after removal of the cerebral hemispheres (see Fig. 9).



FIG. 9. A pigeon with the hemispheres of the brain removed (according to Flourens). The pigeon *does not* react when shown a cat

its master and attempts to bite the laboratory attendant who comes to clean its cell.

I. P. Pavlov and his collaborator Zeleny, who also worked on the removal of the cerebral cortex, succeeded in establishing more exactly the character of the injury to the nervous activity of an animal deprived of its cerebral hemispheres.

In Pavlov's laboratory experiments, a number of conditioned reflexes were elaborated in the animal before the operation. Only after this had been done was Goltz's operation of extirpation of the cerebral cortex carried out.

It was found that after the operation, when the former conditioned stimulus was applied to the dog, for instance the ringing of a bell, it was not followed by any secretion of saliva. The unconditioned reflexes, however, were still present. As Goltz had discovered, such a dog remained in good health physically, possibly even in better health than animals not operated on that received the same food and were kept under the same conditions. The normal dog, as is well known, performs a variety of movements from which a dog deprived of its cortex can be said to be liberated. It might be said that the operated animal gives the impression of an idiot, *i.e.* it has lost all the advantages of higher nervous activity, remaining capable only of eating and sleeping.

Another pupil of Pavlov, Zavadsky, extirpated the entire cortex except for a small fragment in the olfactory area. He noticed that such an animal became insensible to all stimuli, such as light, sound, temperature, electricity, chemical substances, etc., but it retained its full capacity for orienting itself

through olfactory stimuli, and through this one sense it could enter into contact with the external world.

This latter fact indicates that particular forms of adaptive activity corresponding to various external forms of energy are localized in particular parts of the brain. This assertion, however, has no absolute validity. It was very soon shown by Pavlov and his older pupils (Tikhomirov and others) that the various regions of the cerebral cortex, while being strictly differentiated, were at the same time capable of replacing one another. Pavlov considered this capacity very important in view of the possibility of injury to the nervous system from outside, in particular of injury to one part or another of the cerebral cortex. The experience of neuropathologists has fully confirmed Pavlov's view of the possibility of far-reaching compensation occurring in the cerebral cortex.

We know now, therefore, exactly what an animal deprived of its cerebral hemispheres loses—it loses its conditioned reflexes. It is of interest to find out what remains after artificially annihilating the entire upper part of the brain, *i.e.* the whole of the cerebral hemispheres. Goltz's experiments have proved that such an animal still retains a great deal. First of all, it retains the capacity of maintaining its body in definite postures and even of locomotion, *i.e.* of overcoming the force of gravity. A similar phenomenon was observed in Sherrington's experiments, where an animal deprived of the entire cerebrum, not merely of the cortex of the hemispheres, was found to be capable of executing reflexly, in response to suitable stimuli, a number of movements similar to walking. In both cases, therefore, a great

part of the mechanism connected with the locomotor reflexes was preserved. But we know also that Goltz's dog retained infinitely more than this, namely, the entire adaptive dynamics of the body connected with the manifestation of complex *unconditioned reflexes* or emotions. In fact, such an animal is *predominantly* an emotional animal; in the language of Descartes, it is governed by the most violent "passions."

A psychologist would say that it was full of anger, if it were not for the fact that this anger was so automatic and purposeless. It may even be necessary to extract the teeth of such an animal to prevent it doing an injury to the person looking after it.

A physiologist would say that such a dog exhibits a very strong expression of only two basic reflexes, viz. the food and defence reflexes. And he would be absolutely correct. As regards the food reflex, it is observed that every day, at about the normal time of feeding, the dog begins to perform monotonous movements, moving aimlessly about the chamber. It is clear, in fact, that this movement is connected with a characteristic "searching" for food. In addition, as already mentioned, the *sex reflex* remains intact and certain elements of playfulness are also retained. Hence it can be asserted that the centres of complex unconditioned reflexes or instincts in the dog are situated not in the cortex but *in the basal ganglia and in the still deeper-lying (caudal) regions*.

It is possible to add yet another observation. Suppose, for instance, some marked unusual sound is made. The operated animal, just like a normal dog, becomes on the alert; it invariably raises its head,

only to lower it again immediately afterwards. But the difference from the normal animal is that if the same sound is made a hundred or a thousand times, the decorticated dog will repeat the same movement each time, while an animal in which the cerebrum is intact ceases to react to the sound as soon as the novelty has worn off. Whether this is good or bad will be explained in the next chapter. The same phenomenon had been observed by Flourens after operations on birds, with certain corrections in view of the simple construction of their cortical apparatus.

When the basic question of the localization of conditioned reflexes in the cortex of the dog had been given a positive answer, Pavlov passed to a more detailed determination of the localization of the various sensory centres, visual, auditory, etc., starting out from the experiments of Fritsch and Hitzig, who had determined the place of the motor centres by operative means.

In place of the previous, relatively crude experiments, such as those of Munk, Pavlov and his collaborators (Elyasson, Kudrin, Krasnogorsky, Saturnov, etc.) employed the method of conditioned reflexes to various sounds, figures or skin contacts (see Fig. 10) with subsequent extirpation of different portions of the cortex. They obtained a fairly detailed picture of cerebral localization, although it was also established by them that the *boundaries* of the various regions are extremely indistinct and that the regions overlap one another.

This circumstance, as also the far-reaching vicariation of the functions of the extirpated regions, has not been sufficiently taken into account by in-

investigators like Lashley, who deny any localization of cortical functions, and suppose that the brain is soaked with physical functions just as a sponge is uniformly soaked with water.

Not long ago Pavlov came forward with an ex-

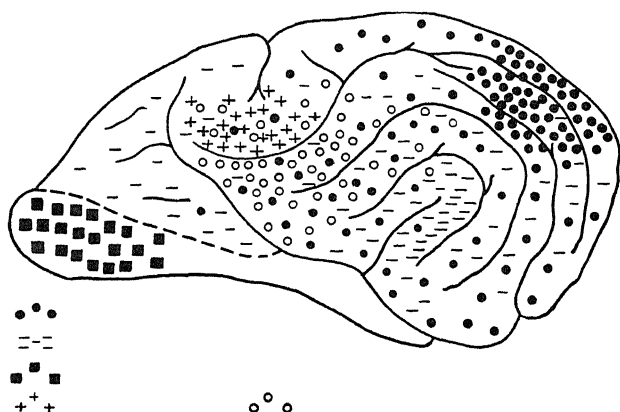


FIG. 10

The localization of certain functions in the cortex of a dog.

- visual analyser.
- sound analyser.
- ■ ■ smell analyser.
- + + motor analyser (according to Pavlov).
- ○ skin and mechanical analyser.

haustive "reply of a physiologist to the psychologists," in which he showed the utter hopelessness of some of the views on the brain maintained by certain neurologists who opposed the ideas of cortical localization.

In point of fact, in order to be able to draw positive conclusions it is necessary, after Pavlov's work, to possess an irreproachable technique for the elaboration

tion of conditioned reflexes. And this is just what Lashley did not have for his experiments.

We must pass now to a description of the modern technique of experiments with conditioned reflexes.

MODERN METHODS OF WORK ON CONDITIONED REFLEXES

How are up-to-date researches into higher nervous activity carried out by means of the method of conditioned reflexes?

Let us suppose that one pays a visit to Pavlov's laboratory in order to become acquainted with the experiments that are being conducted there. On entering the quiet street, now named after Pavlov, on Aptekarsky Island, it is possible to recognize the site of the laboratory from some distance by the faint sound of dogs barking. Before the building of the laboratory itself stands a memorial erected to a laboratory dog. This memorial was unveiled on August 8, 1935, at the time of the Fifteenth International Physiological Congress.

It is morning. The laboratory attendants, in white overalls, come into the large stone "feeding-room" and select the dogs to be used in the day's experiments. One need not imagine, however, that these dogs are destined to die even for the greater glory of science. The experiments about to be described do not require many animals to be sacrificed, but they do demand extreme patience on the part of the experimenter.

At this spot has been erected the so-called "Tower of Silence" (Fig. 11), constructed after the model of up-to-date seismological laboratories. It has two



FIG. 11. The "Tower of Silence"—the laboratory for the study of higher nervous activity in the
Institute of Experimental Medicine (Leningrad)

storeys, each with four sound-proof chambers. On entering the laboratory, one not only sees no trace of blood but one does not even see the dogs themselves. The first impression is one of solemn silence—carpets in the corridor, conversation conducted in whispers, etc. The sound-proof doors are tightly closed, and bolted with large bolts, and the laboratory workers sitting at them are themselves cut off from the surrounding world by a complex system of barriers. They gaze into special optical instruments, from time to time pressing one of the keys in front of them, and making entries into their record books (Fig. 12).

On all sides can be seen hundreds of conducting wires and pneumatic tubes. Somewhere an electric clock is ticking, still more emphasizing the silence prevailing in the laboratory, and short signals are given out by a special radio instrument indicating what is taking place inside the isolated chambers. Saliva-recording instruments are at work, recording the number of drops of saliva secreted, but the dogs themselves are nowhere to be seen.

The whole scene, with the tightly-closed doors, sound-proof walls, tense expression on the face of the experimenter sitting at the periscope, and the numerous instruments of precision, is somewhat reminiscent of a submarine ready for battle.

After an hour or an hour and a half of intense work, the experimenter closes his record book, switches off the current and clock mechanism, and says something like the following: "Well, our experiment is finished ; we will go into the chamber ; the dog has given excellent reflexes today."

The heavy bolts are undone, the double door is

slid aside, and on entering the chamber one sees—an ordinary dog eating biscuits from a special food receptacle provided with an electrical conductor.

The dog itself stands in a special harness and has a glass vessel provided with rubber tubes attached to its cheek. Its food, consisting of meat powder, is divided into 10–15 parts, each part weighing 15–20 grams. The numerous experimenters, working in two shifts, deal with some hundreds of animals each day. Each experiment yields 100–200 figures, of which the most important are 20–30 figures denoting the number of drops of saliva secreted during the period of isolated action of the conditioned stimulus and the length of the latent period.

A modern physiological laboratory possesses a technical equipment on a level with that of a large ship or average factory. It must have a large collection of well-tested instruments for accurately and clearly acting on the complex of nerve cells situated in the highest, most elaborately constructed, parts of the dog's cerebral cortex. Sensitive instruments are also necessary in order to measure the responses of the brain, *i.e.* the conditioned reflexes.

THE INVESTIGATORY REFLEX AND ITS DERIVATIVES

Let us now approach closer to the main subject of the theory of higher nervous activity and its components. First of all, what is the “enemy” against which the physiologist has to contend which makes all this elaborate equipment necessary?

This enemy, the fear of which has compelled the erection of the “Tower of Silence,” and which

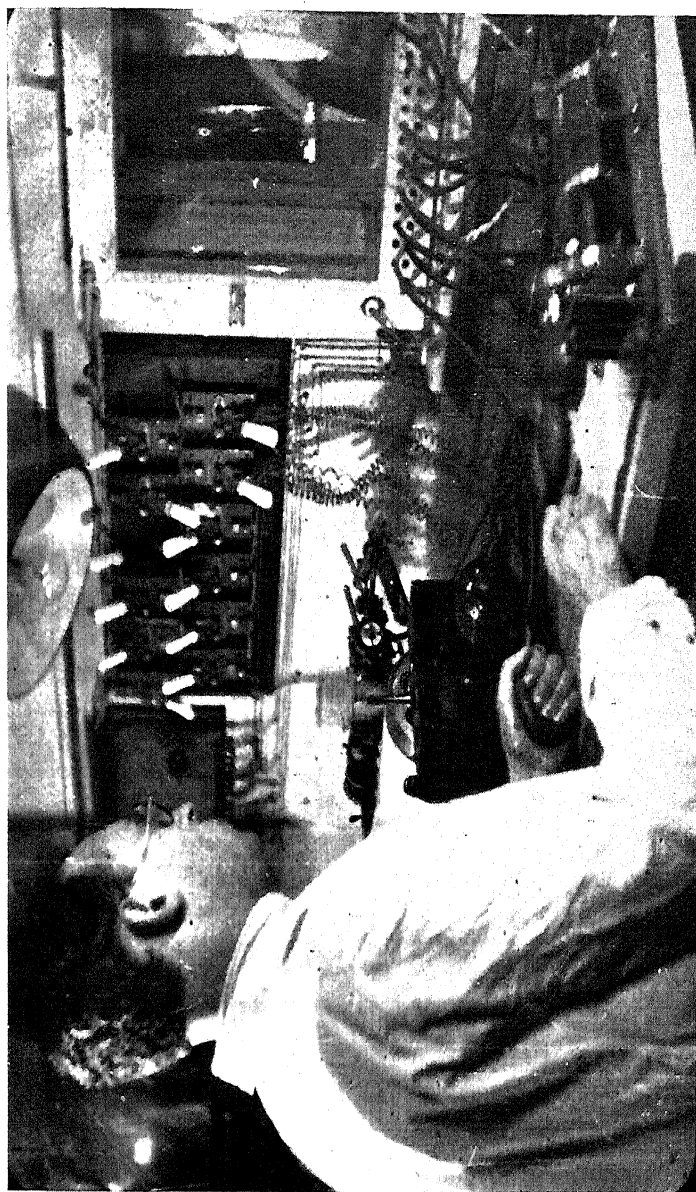


FIG. 12. The automatic transmission of all stimuli in a sound proof chamber with a dog inside

works such havoc to the calculations of subjective psychologists, is termed by the physiologist the investigatory reflex. This reflex was mentioned above in speaking of the reactions of the decorticate animal. The investigatory reflex is encountered not only in such dogs but in all dogs, and indeed in all animals, although it is not always so sharply expressed.

Like other reflexes, this reflex has its starting-point in the external environment. It is connected with a number of centres in definite regions of the brain, and it has its executive mechanism in a number of muscles controlling movements of various parts of the body. These movements are those of the eye muscles, the neck muscles, the muscles of the outer ear, that enable the organ of hearing to be adjusted to a more favourable position in relation to sound, and the muscular apparatus of the nostrils. If any odour is given off by an object, the last-named muscles immediately begin to contract. Their function is a very important one in the dog, for the latter's first and chief method of acquaintance with the external world takes place through the olfactory sense. In general this apparatus possesses a high degree of development in animals. In man, orientation through olfactory stimuli is of comparatively little importance. Darwin has shown, however, that in man the expression of many emotions is connected precisely with the functioning of this inhalatory mechanism. He also connects with this function the development of certain so-called mimetic muscles of the human face.

The most important mechanism for immediate connection with the external world is the motor apparatus of the eye. In accordance with this the

visual centres in the brain are connected with an additional centre, stimulation of which by an electric current is followed by movement of the eyes. The capacity for orientation based on judgment by the eye depends entirely on such ocular movements and their co-ordination.

In regard to the functional character of the investigatory reflex, it has been firmly established that this reflex is inborn, as can be judged from the fact that it occurs in a dog deprived of its cerebral cortex, when it is still exhibited in a sharply marked form. In this respect, therefore, it is a representative of the unconditioned reflexes. On the other hand, in one respect it is essentially distinct from the remaining unconditioned reflexes, viz. that in normal animals, on repetition it is inhibited and disappears. This is understandable, for repetition of a new sound or visual stimulus does not require any further special attitude or orientation on the part of the animal.

We have said that the investigatory reflex is *extinguished* on repetition. If, however, it were a *genuine* inborn reflex such as the food or sex reflex, it could not be extinguished under any circumstances.

Can it be then that it is a conditioned reflex? No, for it is sharply distinguished from all conditioned reflexes inasmuch as we find it fully developed almost from birth. The investigatory reflex is ready prior to any application of it. Hence we are justified in calling it a boundary reflex; in one respect it has the firm basis of an inborn characteristic, in another it has the unstable basis of acquired reactions.

What is the effect of the investigatory reflex when it manifests itself? It inhibits all other reflexes, and *first and foremost* the acquired reflexes. In relation

to the investigatory reflex, all conditioned reflexes become divided into two groups: old conditioned reflexes are sometimes only slightly inhibited under its influence, young conditioned reflexes disappear altogether. Consequently, the investigatory reflex is the best test of the stability of a conditioned reflex. But it is, of course, a test that should not be abused.

It is interesting to enquire what happens to the investigatory reflex when it is extinguished, and whether it disappears for ever? It is difficult to establish conditions in which one and the same stimulus acts during a number of years in a completely uniform environment and with absolutely uniform strength. In point of fact, there is usually a changing environment and a changing complex of stimuli, the latter especially varying in strength. In such circumstances the investigatory reflex is continually renewed in a more or less marked form. This reflex is the physiological basis of *attention*, just as the conditioned trace reflexes, of which we shall speak below, are the physiological basis of memory. The essential task for every experienced teacher consists in maintaining the investigatory reflex at a sufficiently high level.

All methods that fail to take into account the investigatory reflex may bring about the extinction of conditioned reflexes. It is sufficient to make only a single too sharp movement or alteration of the voice, and the conditioned reflex at once becomes inhibited. There is, however, also the opposite extreme which, unfortunately, is frequently encountered in practice. One and the same stimulus is sometimes repeated many times in succession in the hope that it will have a greater effect. But the

effect is often exactly the reverse; the reflex to novelty is extinguished, and this extinction inhibits all other reflexes. The result is general limpness and sleep, a subject dealt with in detail later on.

In speaking of the investigatory reflex or reflex to novelty, Pavlov frequently had recourse to the following comparison. One frequently sees notices in museums, or even in shops, requesting visitors not to touch the articles exhibited. Can it be true that museum visitors are in need of such frequent and strict warnings? However strange it may sound, the fact is that, if it were not for such notices, the valuable exhibits would be soiled or reduced to fragments by the amount of handling they would receive. To prevent this requires also a whole system of protective measures, supervision over visitors, etc., for only at a very high cultural level, and even then not always, do such visitors lose their need to touch objects looked at.

Thus the investigatory reflex in response to a new stimulus constantly passes into the touch reflex; it represents, as it were, a weak form of the reflex of grasping objects. Of course, with a certain amount of training, a person becomes satisfied with simple examination of objects by the eye; he becomes capable of elaborating lasting conditioned reflexes without recourse to the primitive means of acquaintance with them by means of touch as, for instance, always occurs in the case of small children.

Chapter III

THE ANALYSIS OF COMPLICATED FORMS OF BEHAVIOUR FROM THE STANDPOINT OF CONDITIONED REFLEXES

CONDITIONED REFLEXES FROM AN ANIMAL'S OWN MOVEMENTS. THE ANALYSIS OF VOLUNTARY MUSCULAR ACTS

IN one of the preceding sections an account was given of the experiments of Sherrington and Magnus, and it was mentioned that an animal exhibits a number of *postural reflexes*, *i.e.* reflexes in which the initial stimulus is the state of particular parts of the body, for instance flexion of the extremities at a definite angle. If a dog is put in a particular posture, this of itself produces excitation in some parts of the nervous system and inhibition in other parts. On these reflexes as the inborn basis it is possible to build up one or other conditioned reflex just as in constructing conditioned reflexes on the basis of eating or self-defence reactions.

In this particular case what is inborn is the basic co-ordination observed in the spinal cord and the lower part of the brain. The conditioned stimulus is the posture which is artificially imposed on the animal.

Let us attempt to attain a conception of the mechanism underlying the various postural reflexes elaborated by an animal during the course of its life. We know that the animal's brain contains a

number of centres adapted to the reception of stimuli corresponding to particular forms of energy, such as light, sound, chemical energy (smell, taste, etc.) (see Fig. 10).

What are the receptor organs that analyse the response movement itself? They are sometimes called the *motor centres* of cortex. In Pavlov's opinion the motor centres of the cortex are not effector organs; they are the receptors of reflexes, the starting-point of which, as in the case of Sherrington's reflexes, lies in the activity (contraction) of the muscles themselves and which participate in one motor action or another. These reflexes form the underlying mechanism of more complex and delicate forms of movement, viz. so-called motor habits. It follows that while, on the one hand, every movement whatever its origin is a result of muscle contraction, on the other hand, every contraction of the muscles itself acts as a stimulus for the nervous system.

We are usually inclined to regard our muscular system as a purely *executive* apparatus, but, as experiment has shown, it possesses at the same time a very refined *receptor* apparatus.

It is correct to say that we possess a special muscle "sense," but we are not able to give such a clear account of where it is localized as we can for the other senses, such as sight and hearing, which are termed "higher." In persons suffering from locomotor ataxia, the so-called deep or muscle sense disappears, and the person affected loses the possibility even of locomotion without outside assistance, not to speak of the finer functioning of the upper extremities.

Many professional abilities connected with the perfection of movements requiring constant testing and control in execution are based on the delicacy of the conditioned reflexes formed by this motor analyser, on the differentiating power of this apparatus contained in the brain. All parts of the brain which are the seat of the centres of visual, auditory, tactile, skin-temperature and other reactions, possess the power of distributing stimuli travelling through the nervous system into separate groups according to their destination, *i.e.* of differentiating them. Hence, Pavlov terms these parts the "central ends of the analysers," correctly noting that their peripheral portions are located in the sense organs. In regard to vision and hearing this is quite clear; in regard to the motor centre, however, it is less evident, but the motor analyser also divides all movements into *groups*; it controls the movements carried out, thanks to the presence of the skeletal muscles.

. Is it the case that the brain centres corresponding to the muscle sense are at a higher level than the other centres, that they control the execution of work? Pavlov maintains that this is not so; he considers that the motor centre is on an equal level with and equivalent to the other analysers, but is one which is adapted solely for analysing impulses coming from within, from the *reacting apparatus itself*.

The reflexes formed from the animal's own movements are called proprioceptive reflexes, as already mentioned in connection with Sherrington's work.

The region termed the motor centre or analyser is

absolutely equivalent to the other analysers. It has been mentioned that on any stimulation of the peripheral apparatus (eye, ear) a more or less powerful excitation is transmitted to the corresponding analyser in the brain; if excitation of the salivary centre takes place at the same time, then a temporary connection is established between the two centres (Fig. 7).

Pavlov's pupil, Krasnogorsky, demonstrated by means of a very simple but ingenious experiment that, if a *compulsory* movement is evoked in the dog by means of a special apparatus similar to that employed in physiotherapy for vibrating joints of an extremity that has lost its power of movement, and if the animal is fed at the same time, then subsequently it is sufficient to vibrate the extremity, and saliva will immediately flow from the duct of the salivary gland.

That is to say, a connection is obligatorily established between the two above-mentioned centres in the brain, viz. the centre for the movement of the extremity and the food centre. This connection is a temporary one. Such reflexes, formed with the participation of the motor analyser, are distinguished from all other reflexes in that if the arc of any other (non-motor) reflex is linked to the food centre, saliva will flow, and with this the whole process terminates.

With a conditioned reflex from the motor analyser, however, the act of salivary secretion does not terminate the reaction but is only the *beginning*; any movement executed immediately despatches a signal to the cortex (the motor centre), and the whole thing starts afresh. This is the reason

that it was for so long believed that the motor centre was a superstructure or controller of other regions. The clinician also adhered to this prejudice. This misunderstanding was only finally dispelled when Krasnogorsky proved the possibility of linking any movement of the animal to the salivary centre, and there is now no longer any justification for speaking of the motor centres as a special region of the brain, as the "seat of the will," etc.

There is only one peculiarity which permits a physiologist to separate the motor analyser from the others to a certain extent; this peculiarity, however, concerns not its central but its peripheral end, *i.e.* the muscle with which the centres are connected. Owing to the conditioned reflex that has been established, the muscle is included in a sort of *ring* connection (A. Semolov). A movement once executed, as it were, returns to the brain, but now in the form of a characteristic impulse, and there it again undergoes the process of testing and analysis. The result is that a kind of multiple control of the correctness of the muscles' activity takes place in the cerebral cortex.

Only by continually travelling in this ring or circle, *i.e.* being continually tested in practice, do the reactions of the muscular apparatus attain that height of perfection which is observed among experts in various branches of activity (pianists, stenographers, linotype operators, etc.). In animals this higher function is exhibited in a much weaker degree.

By determining, therefore, the basic laws of higher nervous activity, first established through the study of the salivary reflexes in the dog,

Pavlov's school gradually included in the field of its research also the sphere of complex motor manifestations or *habits*. It was found that any muscular movement could be linked to the salivary gland, that is, it could be made a conditioned stimulus. Krasnogorsky proved that for this purpose it suffices to evoke the given movements by a passive means, *e.g.* by vibrating the extremity, and afterwards to "reinforce" the movement by feeding.

In this way an analysis was made of the fact already noted by the American behaviourists as "the method of trial and error." Thanks to Krasnogorsky's experiment described above, it was shown that certain defects previously ascribed to Pavlov's method, *viz.* the omission to take into account movements of the animal, on a parallel with salivary secretion, were actually a merit. It turned out that for a certain period it was more advantageous to concentrate attention on a single object, the salivary reaction, in order to establish the basic laws of the activity of the cerebral cortex by this means, and then to bring these into relation with movement.

On the other hand, while the American psychologists at the present time have only one form of control, *viz.* movement, at their disposal, Pavlov has two, *viz.* secretion and movement, and by a comparison between them he was able to construct a new theory of voluntary motor actions.

In what way, however, are we to bridge the gulf between the study of the mechanism of passive movements, as spoken of above, and the study of voluntary movements such as were so much the concern of investigators before Pavlov? Krasno-

gorsky's experiments, as already mentioned, dealt solely with compulsory movements. According to Pavlov, however, the difference between the two categories of voluntary and involuntary movements is not at all one of principle but lies only in the character, the dynamics, of the corresponding nervous processes.

A long while ago, during the first experiments with conditioned reflexes, it was noticed that a dog, on being placed in the stand and fed at definite intervals of time, sometimes, under certain conditions, begins of *itself* to press the starting device without waiting for the signals of the experimenter. This device enables the dog to obtain access to the automatic feeding receptacle already mentioned in the description of the laboratory. It is as if the dog carried out an experiment for itself and obtained food.

Let us attempt to analyse this characteristic chain of phenomena. It is obvious that if any movement of the animal were to enable it to prolong the time of eating even for a few seconds, by holding back the automatic feeding receptacle, such a movement would obtain a pre-eminent position in the cerebral cortex and would begin to be regularly performed by the dog. Such a phenomenon corresponds to the method of trial and error used by American scientists, where the animal of itself finds its way out of a cage provided with barriers, or gradually finds the way out of a maze after carefully sniffing and searching all the corners. In the case under consideration, however, a dog, and particularly a more highly developed animal, such as a fox, brings about the movement of the feeding-box under

absolutely *tranquil* conditions. Here no sort of trial and error is to be observed. Is it perhaps the case that the movement is carried out voluntarily?

Pavlov showed in one of his latest researches that this so-called voluntary movement and many other similar movements have their explanation and real foundation in the structure of the conditioned brain connections. In the case under consideration, the phenomenon depends entirely on peculiarities in the course of the nervous process, peculiarities which were previously only suspected but are now fully known. We have in mind here particularly the experiments of Miller and Y. Konorsky.

Miller and Konorsky, working in the laboratory of a Polish hospital and using very primitive means, investigated conditioned reflexes and performed the experiment described above in which the dog obtains food, without, however, using any automatic feeding receptacles or other complicated devices such as were at this time already in use in Pavlov's laboratory. Being interested in the motor receptor and its characteristics, instead of using any apparatus they merely placed the forepaw of the dog on a low wooden block, after which they immediately gave it food. The dog ate the food given it, saliva flowed from a salivary fistula; in short, the experiment on the formation of a conditioned reflex was carried out in the usual way.

After a certain time, however, it was noticed that it sufficed for the experimenter to begin the preparations for the experiment, and the dog would of itself begin to flex its paw at the appropriate joint. The dog as it were saluted its master with its forepaw. Such a thing frequently occurs in ordinary life—for

instance, when a dog is trained to present one of its paws on command, being usually rewarded by receiving some titbit.

Miller and Konorsky then attempted to form a conditioned stimulus from this same flexion of the paw, but not on the basis of giving *food*, but of pouring some stimulating substance—acid—into the mouth. However, with the presence of salivary secretion they not only did *not* obtain any flexion of the paw, on the contrary they found that the paw underwent a marked and prolonged *extension*, depending obviously on the action of the antagonistic muscles. In this case, where it was a question of acid, when the experimenter approached the dog the latter greeted him with an exactly opposite gesture, namely with an extended and as it were petrified forepaw which it was not even possible to bend. The authors came to Pavlov's laboratory with a detailed report of their discovery, and they confirmed it there, in addition making it the subject of a special book on voluntary movements which was published in Polish with a preface by Pavlov.

This discovery did not come unexpectedly for those who had attentively followed the gradual development of Pavlov's theory of temporary connections in the cerebral cortex, a theory which forms the foundation of the whole theory of conditioned reflexes. At a certain stage in the strengthening of these connections, *i.e.* with a *well-beaten track* between the point of the conditioned reflex in the cortex and the point of unconditioned stimulation in the lower lying centres, a close and lasting connection must be established, and in actual fact is established, between them. When the *food* centre

is stimulated by hunger, this connection may function in the reverse direction also; the nervous process may alter its direction and proceed immediately from the food centre to the cortical cells. The result is that it suffices for the experimenter to show himself before the eyes of the hungry dog, and the reflex in the form of the movement of the paw occurs independently.

Two important questions were settled by this experiment. In the first place, one of Darwin's laws of the formation of useful associated habits received a physiological explanation, and in the second place, the mechanism of voluntary movement, at any rate in animals, was for the first time clearly revealed. It is hardly necessary to add that this discovery of the phenomenon of voluntary action had an entirely different character and different consequences from those proclaimed by the zoo-psychologists who had more than once discovered the voluntary character of animal movements and connected it with mind. The whole problem now lost its disturbing "mysterious" character, and in return it gained enormously in clarity.

Thus Pavlov, without going outside the physiological field, gradually approached an analysis of the phenomena of voluntary actions. In that case, it may be asked, why did he for thirty years and more deny any justification for using the term "voluntary," and even establish a system of punishments for his workers if they did so? The reason is that he did not consider it permissible for a physiologist to use terms the physiological significance of which had not been fully cleared up by him and his school. Moreover, such procedure led to confusion even in

the sphere of human psychology. Pavlov was far too well acquainted with the history of human culture, in which the element of voluntary movement has such an enormous part, for him to deny the existence of consciousness. But he was justified in studying the roots or germs of voluntary action, beginning from its very lowest forms. Only on finding, after thirty years, these roots in the above-mentioned phenomenon of *reciprocal* connections in the cerebral cortex did he begin to speak of the development of this capacity in a number of organisms, culminating in man.

It is frequently asserted that Pavlov adopted a negative attitude to philosophy, but this is not true. In one of his lectures he remarked:

“The philosopher, himself personifying the highest human aspirations of synthesis, though up to the present time this synthesis has been fantastic, striving to give an answer to everything that concerns man, must now create a whole from the objective and the subjective. For the natural scientist everything lies in the method, in the chances of attaining a steadfast, lasting truth, and solely from this point of view, one that is obligatory for him, is the soul, as a naturalistic principle, not only unnecessary for him but even injurious to his work, limiting his courage and the depth of his analysis.”¹

Such were Pavlov's words at an early stage of his work when he had only just begun the study of higher nervous activity, but they were confirmed by him at the end of his life when he had collected tremendous data relating not only to animals of various degrees of development but also to man.

¹ Pavlov, *Lectures on Conditioned Reflexes*, p. 60, 1928.

The phenomenon of *reverse movement* of the physiological process along the connecting elements of the cerebral system, which has hardly yet won a place among the conceptions of modern histologists and representatives of the general physiology of the nervous system, in point of fact opens the door also to understanding the most complex subjective experiences of man.

We shall see later that these reverse connections, especially under the influence of illness but of course also under normal conditions, sometimes become so pronounced as to reach the degree of hallucinations. As we shall see below in more detail, Pavlov's analysis proceeds by means of these comparatively rare but extremely sharply expressed cases of the distortion of normal cortical activity, and leads him finally to a new understanding of diseases connected with the derangement of voluntary acts. For the time being it is only necessary to note that Pavlov attempted to construct a material physiological basis for the theory of voluntary actions. He developed a new theory of primary and secondary signalling systems in the cortex, the latter of these being characteristic of man alone.

PAVLOV'S LATEST THEORY OF TWO SYSTEMS IN THE CEREBRAL CORTEX

Let us pass on to an account of a very interesting section of Pavlov's theory, viz. that of the three centres or systems arising in the central nervous system during the process of evolution of its functions. The first of these formations is the system of subcortical centres of ganglia "most closely

adjacent to the cortex." This is the region of complex unconditioned reflexes or instincts, in psychological terminology the region of emotions or wishes, which is closely connected, as is recognized by endocrinologists, with the chemistry of the organism and its changes during the various cycles of life. It is these centres that give the organism a sufficiently firmly based orientation in relation to the environment and ensure equilibrium, but this orientation is strictly limited to a small number of situations (hunger, self-defence, sexual excitation) and is far from adequate for establishing higher degrees of adaptation.

Above the first system, and on the basis of it, is a second cerebral system, that of the centres of conditioned or temporary reflexes. As will be apparent from what has been said above, this system, represented by the general mass of the grey matter in the cerebral hemispheres, has the advantage of ensuring a considerably wider orientation of the organism and of connecting it through the activity of its sense organs or receptors with all the phenomena of the external world. This result is attained, thanks to the fact that the corresponding reflexes are extremely labile formations which are established or annihilated as required, thus enormously extending the capacity of the animal to adapt itself to the ever-changing conditions of the external world and to manœuvre freely under these conditions. In the vast majority of animals, however, this essentially represents the climax of higher nervous activity.

In animals, this higher region of the cortex represents an *immediate* projection of the external world; it is an assembly of *analysers*. In the case

of the human brain, however, during the process of its development, during the process of verbal human intercourse and the conquest of labour by means of tools, yet another physiological superstructure makes its appearance, viz. an organ which is formed on the basis of the above-mentioned second system, an organ which synthesizes and generalizes the activity of the immediate projections, and serves as the material substrate of a new capacity of much later origin, the capacity of *abstraction*.

According to Pavlov, this third (or second, if we disregard the subcortical) system for establishing highly complex mutual relations between the organism and the environment is located primarily in the *frontal region of the cerebral cortex*. This is in agreement with the fact that the frontal parts of the cerebral hemispheres attain their real development only in man.

Human speech, regarded from the physiological standpoint, is the most widespread means of mastering the surrounding world and of generalizing all preceding experience. This experience, as Pavlov admits, in its higher forms provides the basis for human practice in general and ultimately constitutes the basis of all scientific knowledge. Consequently, the frontal parts of the cerebral hemispheres in man, considered in the process of man's historical development, assist him to arrive at knowledge of natural laws and therefore allow him to master natural forces and to transform them for his purposes.

It is true that a fundamental problem remains unsolved, viz. the problem whether the frontal

lobes, the rudiments of which we find in all higher mammals, are the seat of the possibility of achieving abstraction and some form of language, and, if so, in what external activities this possibility is expressed. We shall return to this question when speaking of Pavlov's experiments with *anthropoid apes*. It was in these experiments that Pavlov first of all adopted a historical standpoint and turned his attention to the history of material culture. He not only recognized the significance of the function of speech; he accorded speech a definite place in the chain of evolutionary factors, and he was on the point of making the characteristic features of this function the subject of special analysis when death interrupted his plans.

There is no doubt that an analysis of the phenomena of *speech* during the period of its development (and not only logical speech but also mimetic and artistic speech) provides the highest embodiment of the laws of formation of conditioned reflexes.

For the behaviourist, abstract thought is not a problem in any way deserving of attention. In his view, thought is to a very large extent "dumb speech," and that is the end of the matter. The behaviourist Watson declares that the behaviourist point of view assumes that thinking is behaviour, but also a motor activity which entirely corresponds to that employed in a game of tennis or golf or any other form of muscular effort. From the standpoint of Pavlov's new theory, all muscular effort, *i.e.* all phenomena *immediately connected* with real reactions of the external world, remain within the limits of the first signalling system, that is to

say at the level of conditioned reflexes. In the succeeding, third stage, *i.e.* in the second signalling system, the connections established may bear no trace of muscular character, *i.e.* not possess any motor character. Consequently, the laws of the coupling and breaking of these connections, what we may call the dynamics of higher nervous activity, may in this case be supplemented by new laws that are likewise physiological but of a much more complicated nature. We repeat that in regard to this section of Pavlov's great theory we still do not possess precise data or fully perfected conclusions based on decisive experiments like those made by Pavlov elsewhere. We dwell here on this working hypothesis of the different systems only in connection with the study of habits, the broad field for investigation of which is supplied with rich and valuable data from the physiology of conditioned reflexes, data that we shall now proceed to examine.

THE FORMATION AND STRENGTHENING OF HABITS IN MAN BEGINNING FROM INFANCY

We all know that man comes into the world as a veritably helpless being with extremely primitive means of receiving stimuli (receptor organs) and extremely meagre means for expressing reactions (effector organs). Hence it is the more interesting to trace the physiological path traversed by a human being in reaching the state of a high degree of adaptation to the phenomena of the surrounding world and social environment. In our times, an adult civilized man possesses the capacity not only of receiving signals that have traversed hundreds and

thousands of miles, but of reacting to them by means of tools, giving him the possibility of accomplishing work many times exceeding his own strength or the strength of previously existing associations of human beings. We refer here to the ever-growing perfection of machinery and its role in the subjugation of new natural forces.

Such being the case, we have every right to demand a satisfactory formulation of the laws of this transition of human beings from primitive utilization of nature to the complex process of mastering its forces. But it would be in vain to seek an answer to this question from modern experimental psychology. An answer is either lacking or, if given, it suffers from extreme vagueness and indefiniteness in its formulation.

Let us begin from the moment of birth. What information can modern psychology give us regarding this interesting period of development of the human being? Can certain aspects of cerebral activity be formed even during the period of *intra-uterine* life?

The well-known psychologist Sully mentions only that foetal life represents a semiconscious state, and he says nothing more on the subject. When then does the human embryo cease to be a semiconscious being? In what month of life (intrauterine or extrauterine) is the formation of consciousness completed? Some psychologists answer this question by giving various periods, others deny the possibility of solving the problem at all. There is no doubt that the numerous contradictions revealed between the conclusions of psychologists concerning the mind of the infant and the data of

physiology are determined by the initial defects inherent in the method of self-observation. Even if it be granted that the method of self-observation does give us some picture of the psychical life of an adult, it can give us nothing at all concerning the psychical activity of a new-born child. Let us turn, therefore, to the position of our physiological knowledge.

What is the beginning of the process of development of the organ that determines co-ordinated activity, *i.e.* what is the beginning of the functioning of the nervous system? The first sign of the development of the nervous system is given by movements of the embryo, taking the form of reactions to definite stimuli during the latter half of its intrauterine life. The amount of such stimuli impinging on the receptor surfaces of the embryo is comparatively very small, although by no means non-existent. Moreover, both the receptor organs themselves and all the central parts of the nervous system, *viz.* the brain and spinal cord, are still morphologically undeveloped. In consequence, the number of reflexes depending on stimuli of the outside world is comparatively very small. On the other hand, the number of reflexes arising as a result of stimulation of the brain cells by the composition of the blood of the mother must be regarded as fairly large.

A human embryo of 2–5 months, possessing only the more simply constructed cortical elements, is still by no means an inert mass. As the data of M. A. Minkovsky¹ have shown, it is constructed like an extremely delicate reacting apparatus.

¹ Symposium in celebration of Pavlov's seventy-fifth birthday, Leningrad, 1924 (Russian).

For his experiments Minkovsky was able to obtain human embryos of various ages from cases of artificial termination of pregnancy. He tested various kinds of reflexes on them; in particular, movements in response to skin stimulation. He established the very important fact that the "behaviour" of these embryo human beings is marked by certain features of great interest from the physiological point of view. For instance, the reflexes are marked by an extreme tendency to "irradiation," *i.e.* the spreading of excitation, when once aroused, over the whole mass of the nervous system. Thus, it sufficed for Minkovsky to stimulate the skin of one extremity (*e.g.* the foot) to bring into action not only the muscular apparatus of this extremity, as is the case in adults, but also the muscles of all the other extremities and the muscles of the trunk, neck and head. This phenomenon of "irradiation" demonstrated that no kind of temporary connection can yet be formed, for stimulation spreads over the whole cortex.

From the moment when the infant makes its entry into the world, the relation between the work of the external and internal receptor organs is sharply altered. The external environment, even if only an ordinary room, causes thousands of manifold stimuli to impinge on the sensory surfaces of the newly-born child. In the first place must be mentioned the relatively low temperature of the air, and next the contact of hands with the tender skin of the infant, the sound of steps, natural or artificial light, etc. The muscular system of the new organism is at once mobilized for response; the skin reddens (an expansion of the vessels of the skin), the

eyes perform blinking movements, the hands and feet make irregular movements and, finally, the infant cries loudly.

At this time we can clearly observe the transmission of stimulation along various reflex arcs, beginning externally and also ending externally, viz. in the motor organs. The starting-point for all these reflexes lies in the action of *external* agents, and they are expressed in the form of movement, the movements for the most part exhibiting a complicated but still chaotic character. There follow the very important stimuli resulting from contact of the infant's lips with the mother's breast, in response to which there occur very soon (although not at once) the exactly regulated movements of suction, that is to say a series of strictly co-ordinated reflexes of the muscles of the lips, tongue, palate and throat. Urination, defæcation, breathing, yawning and sleep complete the enumeration of these elementary reflex activities.

Such is the first stage in the process of development of reflexes. Is it not remarkable that we should encounter at the very outset complicated, co-ordinated reflex activities, such as the act of sucking, which exhibits an extremely high degree of co-ordination in the functioning of the separate organs in relation to one another and of adaptation in the functioning of the organism as a whole in relation to stimuli coming from outside (seizure of food)? There is really no occasion for surprise here, since during the first few days of life this act in mammals is the sole one necessary for the organism to obtain the nourishment without which its existence could not continue. This does not mean, however, that this reflex

operates at once and without mistakes. The sucking reflex is inborn, like the reflexes acting on the iris controlling the size of the pupil in response to light and other unconditioned reflexes, but from its first appearance it undergoes considerable *correction* by conditioned reflexes, so that it is not always easy to determine its innate basis.

What is the picture of the further development of these elementary activities? Let us suppose that a cell of the infant's food centre is in a state of excitation. We know that this excitation is governed by biochemical laws; the blood, having used up the nutritive material received on its first nourishment, undergoes a change of composition and acquires the properties of "hungry blood" (Pavlov). In this way the cell of the food centre comes into a state of excitation. At the same time a multitude of stimuli fall on the sensory surfaces; thus the sight of the mother's breast acts on the eye, the contact of her hands acts on the surface of the skin, etc. All the cells corresponding to these stimuli, situated as mentioned above in the cerebral cortex, come into a state of more or less considerable excitation. If following these stimuli the infant actually receives in its mouth the milk necessary to the organism, then in the nervous system stimuli travel from the weakly excited centres, in this case from the visual and olfactory centres, to the more strongly excited centre, viz. the food centre.

In this way the first conditioned reflex is formed, and with succeeding trials the infant of itself reaches for the breast of the mother or the bottle from which it is artificially fed.

This reflex constitutes an individual acquirement

of the given organism, that is to say an acquirement obtained during the course of its extrauterine life. Until this moment, that is until the completion of the first act of suction, the infant, as far as its cerebral cortex is concerned, does not differ in any functional respect from other new-born infants. From this moment, however, *i.e.* from the time of formation of the first cerebral reflex in the proper sense of the term, it becomes distinguished from its coevals. This distinction occurs because the combination of visual, tactile and other stimuli (for instance the sight of the mother, her stature, methods of care) are essentially different in each particular case, since any one mother differs in individual characteristics from another. Thus the first stone is laid for building up the child's *individuality* in the physiological significance of the word, although, of course, peculiarities of the chemistry of its body that are sometimes inborn also play a certain part.

Within a few days (sometimes earlier, sometimes later—here individuality begins to be exhibited) the hungry infant unerringly reaches for the mother's breast, *i.e.* we observe its motor actions occurring before the food stimulation has taken place, and, moreover, we observe them executed in a more perfect form. Here the above-described mechanism of reverse temporary connections begins to be exhibited.

Very quickly the child begins to react not only to what is taking place at the moment but also to what has occurred some time back, thus very greatly extending the possibility of reacting to the world.

In regard to the next stage of the child's development, especially the beginning of crawling, walking

and other natural movements, here also abundant data are provided by applying the physiological conception of the formation of conditioned reflexes. These data, however, have not yet been fully systematized.

While animal locomotion, including that of the higher mammals, takes place, as we have seen, thanks to the establishment of a complex chain of reflexes in the spinal cord, hind-brain and mid-brain, the first locomotory movements of a child possess yet another link situated in the cortex of the cerebral hemispheres, evidently in the motor analyser, about which a good deal has already been said.

If it were not that this new system which has arisen in the process of evolution was functionally distinct from the old systems, a newly-born child would be able from birth to move about and follow its mother as occurs in certain mammals (*e.g.* ungulates). Actually, we observe that it takes a child more than half a year to learn the elementary forms of locomotion. Even after a year its movements are marked by an unconfident, hesitating character. Traces of embryonic, undifferentiated movements are sometimes observed even up to five or six years of age. On the other hand, when these complex locomotory movements have finally been elaborated, it is found that any destruction of the integrity of the cortical apparatus or motor analyser is first of all expressed in its effect on locomotion. While Flourens' pigeon from which the cerebral hemispheres had been removed could still walk and fly, and a dog operated on by Sherrington's method could still maintain its equilibrium, a human being suffering from even a small hæmorrhage in the

region of the higher cortical centres is immediately deprived of the power of movement.

This fact of the gradual complication of what might appear to be a very simple motor act is far from being unique of its kind. The cerebral hemispheres, and in particular the cortex, are the product of many thousands of years of evolution, and they are bound up with the highest stage of evolution, the subjugation of the forces of nature itself. Consequently, this organ has become ever larger and more complicated, and has gradually come to overrule the centres of more elementary motor acts, the sphere of activity of the organs of nutrition, vasomotor system, internal secretion, etc.

In the language of pedology this period is characterized by the fact that the child begins "to control the natural functions of its body." At the same time the child begins to associate with other children of its age.

During the same period or a little later (all data here are, of course, very approximate and depend on place, epoch, social environment) the child develops the capacity of *speech*, which, considered in the general scheme of development of conditioned reflexes, is of enormous—perhaps decisive—significance for the development of the functions of the second signalling system. Pavlov agrees with many other scientists in ascribing a primary role to speech in the origin of man's power over nature, although, following Bacon, he points out a certain impotence of words as a means of reflecting truth, and he calls words only "signals" of reality.

On one occasion, in conversation with his pupils, Pavlov defined his attitude to this important question

in the following way: "Human thought appears before us draped as it were in three coverings. The first is the most modest, but at the same time the nearest to truth—this covering is movement. The second or middle covering is more ornate—this consists of written signs and graphic symbols. Finally, the third is the most luxuriant, but also the most superficial—this is the covering of verbal signals, the symbolism of speech, which is removed from the immediate expression of thought by both the preceding."

Chapter IV

PAVLOV'S VIEWS ON THE INHIBITION OF CONDITIONED REFLEXES

YEROFEYEVA'S EXPERIMENT AND SHERRINGTON'S OPINION OF IT

THE question of inhibition is not a new one for physiologists. Beginning with Weber, who obtained inhibition of the activity of the heart on stimulation of the vagus nerve as early as 1845, the history of the subject can be traced by way of the experiments of Sechenov on so-called central inhibition of reflexes to the experiments of Sherrington and Magnus. As regards the internal mechanism of inhibition, a subject very closely linked with the diverse views of physiologists on the phenomena of life in general, we owe a great deal to the contributions of du Bois, Raymond, Pflüger, Verworn and N. Wedensky. Nevertheless, among all these theories Pavlov's theory of inhibition is particularly illuminating.

Let us begin by describing his experiments on the inhibition of unconditioned reflexes. We remarked previously that physiology has to deal with several basic unconditioned reflexes, viz. the food, defence and sex reflexes, with the addition, to a certain extent, of the investigatory reflex. The latter, it will be recalled, is distinguished from other unconditioned reflexes by the fact that it is capable of rapid extinction on repetition.

These reflexes, like all their more simple primogenitors, and notably the movements of lower animals studied by Loeb, Jennings and others, are capable of entering into definite mutual relations with one another. A study of the history of these mutual relations provides the essential preliminary basis for Pavlov's theory of inhibition. In the process of their work on conditioned reflexes, Pavlov and his pupils very frequently encountered the following question: What is the relation between the strengths of the unconditioned food, sex and defence reflexes? When do these reflexes reinforce one another and when do they interfere with one another?

The basic fact which forms the starting-point of the study of these mutual relations, or, as Pavlov sometimes expressed it, the study of the hierarchy of inborn reflexes, is to be found in the work of Yerofeyeva as published in her dissertation of 1912.

The experiment with which her name is connected is as follows: Let us suppose that we take an animal which is put in the stand every day and given meat-biscuit powder; this food, however, being only part of what it receives at the end of the work after returning to the feeding-room. This was the regular procedure adopted in Pavlov's laboratory during the investigation of higher nervous activity, which requires that at the time of the experiment the food centre should be in a state of average excitability.

Suppose now, beginning from a particular day, our animal, on being placed in the stand for the experiment, is subjected not to a sound or light stimulus but to electrical stimulation of the skin, which at a certain degree of strength produces a very marked

defence reflex in the dog. In all dogs such stimulation of the skin evokes a complex defence reaction which is expressed by the animal beginning to bite, to kick out with its feet, to tear itself free from the straps holding it, and finally to run away if it is not held by special means. It should be added that during the whole period of stimulation our experimenter offers the animal food and tries to get it to eat. Nevertheless, the result is negative; the animal not only refuses to take food but even begins to exhibit a negative reaction to the whole of the experimental surroundings; it does not come willingly to the chamber in which the experiments are conducted but has to be brought there by force, although previously it came eagerly in the expectation of food.

Thus in this case the fundamental and important unconditioned food reflex is inhibited under the influence of a stronger competing stimulus, the electric current. An analysis of this simple fact suffices to show that unconditioned reflexes, these constant participants and basis of the activity of the whole nervous system, are far from always being exhibited at full strength. The appearance on the scene of a new unconditioned reflex, initiated by a new, sufficiently powerful stimulus, such as the electric current, immediately *suppresses* or *inhibits* other forms of activity that are likewise inborn. This is the first form of inhibition, termed by Pavlov simple, or *external, passive* inhibition.

But Yerofeyeva's experiments went further. In order to heighten the excitability of the food centre, let us suppose that we cease to give the animal any food outside the experimental room and thus bring into play the powerful stimulus of hunger. After

a short time it is observed that hunger begins to have its effect; the dog begins to react more quietly to being introduced into the experimental chamber, the external reaction to the current somewhat dies down, but still the dog refuses to eat. The impress of inhibition is still stamped on all circumstances connected with the hurt received.

A few days pass, perhaps a week, and the animal begins to grow thin and lose weight, but it still comes unwillingly to the experiment. Nevertheless, thanks to the impoverishment of the blood in respect of nutritive substances, the food centre becomes more and more excitable.

By means of hunger we as it were impart a charge to the food centre, increasing its excitability. The further the exhaustion of the blood proceeds, the higher becomes the "charge" of the food centre. After losing a considerable proportion of its weight, the animal gradually ceases to resist and begins little by little cautiously to take food. Then the current is switched on again and the whole story is once more repeated, but this time in a much weakened form.

Continuing our observations, we find that gradually all those stimuli which previously evoked a whole series of defensive movements coupled with the self-defence centre, now begin to be linked to the food centre, until finally the following situation is obtained. The animal stands quietly on the stand and awaits food. It suffices merely to switch on the electric current and the dog begins to wag its tail and to exhibit a number of obvious "food" reactions, the chief of them being the process of secreting saliva. On gradually increasing

the strength of the current, the food reaction does not diminish. Thus, a conditioned food reflex to pain has been established.

In this case, in Yerofeyeva's experiment, we have as it were a *switching over of the nervous energy from the centre of defence movements to the centre of food movements*, the previous reaction becoming inhibited. Those movements of the dog which were previously directed towards completely different requirements, for instance opening the mouth in order to gnaw the straps, are now found to be switched over to absolutely different aims and objects, *i.e.* for better grasping its food, even if the food itself is not yet visible. The entire behaviour of the dog has a completely different appearance from that shown during the elaboration of the reflex. Instead of tenseness of the extremities and vertebral muscles, the dog displays expectation and affability as in the previously mentioned observations of Darwin (see Fig. 5a), not to speak of the fact that we have an additional indicator of the newly elaborated conditioned reflex, *viz.* secretion of saliva, which was not at Darwin's disposal.

By this experiment, which in a way recalls the Roman story of Scaevolius, it became possible for the first time to demonstrate clearly the tremendous role played by the physiological charge of the food centre in an instance comparable to a small episode in the struggle for existence.

The story is told by the scientist G. Bohn, that when Sherrington—who happened to be present at the time of this experiment in Pavlov's laboratory in the Academy of Medicine—saw the changed behaviour of the dog, he exclaimed: "Now I under-

stand the joy with which the Christian martyrs went to the stake!"

In this experiment, however, we have much more than material for historical analogy; we have the possibility of tracing the origin of a *new chain of reflexes*, one of the chief links of which was not any external stimulus but an inborn unconditioned reflex to pain.

This simple experiment demonstrates better than anything else the strength and value of the physiological method in analysing complicated cases of the "struggle for existence," cases when animals sacrifice the integrity of various parts of their bodies.

However, confirmatory experiments also performed by Yerofeyeva demonstrate that this situation (the development of inhibition in a focus of defence movements and the origin of a positive conditioned reflex to pain) actually arises *only* in cases of a medium degree of strength of the stimulating agent (the electric current). When the experimenter began to increase the strength of the current to an extreme degree, the conditioned reflex to pain was *not* formed and consequently there was no longer any inhibition in the pain centre. The dog endeavoured to escape from the stand just like all dogs before they had been subjected to the special procedure.

A further important point should be mentioned. When Yerofeyeva applied the same current of an average strength to *different* places on the skin, a state of chaos resulted which was subsequently designated the *rupture* of the higher nervous activity. Further mention of this will be made later on.

Hence, the central nervous system has no place

for an unchanging "hierarchy," it has *no place for a constant, fixed mutual relation of such processes as excitation or inhibition*. These processes are continually changing, one gives place to another which in its turn yields to a third. Theoretically speaking, we can charge any centre to any degree, since all the remaining centres will have to "efface themselves" before it.

It is possible to give a clear example from the struggle of animals for food, an example very familiar to hunters and naturalists. In this struggle the animal frequently sacrifices the integrity of the superficial skin tissues. In particular, it readily sacrifices the skin of its ears and back. But it is sufficient for the attack to touch the ventral surface of the body, which is in close proximity to such biologically important organs as the heart, intestines, etc., or for the teeth of the animal to penetrate to the bone, and immediately the defence reflex regains the upper hand and the animal deserts the place of combat.

Jack London's novel *White Fang* describes some unforgettable scenes of this character. We see the same thing in the struggle of male birds for the hen bird; in the mating season the former are ready to sacrifice all their feathers and ornaments in the struggle, and apparently become insensitive to wounds. At such a time the sex centre appears to predominate in the male birds to such an extent that all other interests are sacrificed and inhibited. As soon, however, as the time comes when muscles are torn apart, sometimes to the bone, or the eyes are injured, one of the male birds gives way, naturally allowing the victor to enjoy the fruits of his victory.

Consequently, conditioned reflexes are by no means always established on the basis of simple inborn mutual relations. They frequently arise as the result of conflict between unconditioned reflexes. In this way a tremendous structure of acquired reactions is built up, such as undoubtedly exists in one form or another in every species of animal.

The above gives an idea of the biology of conditioned reflexes. But another extremely important physiological conclusion can be drawn from Yerofeyeva's experiments, viz. seeing that we are able to switch over the energy of the nervous system from one centre to another so that one unconditioned reflex becomes a signal for another, the data provided by conditioned reflexes should be even more valuable. In fact, experiment proves that inhibition, even in its very simple passive form, is easier to study with conditioned reflexes than with unconditioned reflexes. By using them for strengthening or weakening unconditioned reflexes, by selecting various conditioned stimuli, we are able to increase even the unconditioned reflex to an extreme degree or to inhibit and weaken it to a minimum. In essence this took place in Yerofeyeva's experiments, where the whole circumstances of the room, as likewise the degree of closeness to eating, act as a conditioned reflex that is at first positive, then negative, and later positive once more. Hence, we pass now to describing another form of inhibition, the so-called *internal* or *active* form. This is closely bound up also with the conception of *negative* and trace conditioned reflexes, the analysis of the external world and, finally, Pavlov's famous theory of sleep and hypnosis.

THE EXTINCTION OF CONDITIONED REFLEXES
AND OTHER FORMS OF INTERNAL INHIBITION

We know that a large number of eminent scientists, physicians and philosophers have worked on the problem of sleep, hypnosis and suggestion. Nevertheless, from the *physiological* point of view, these questions have hitherto received very little explanation and hence much room has been left for imagination and speculation.

Nevertheless, sleep and hypnosis not only possess very great theoretical significance but are of very great practical interest. It is sufficient to remark that an ordinary human being passes about one-third of his or her life in a sleeping condition (assuming eight hours daily being allotted to rest), while suggestion is used by physicians for curing many serious nervous disorders, especially narcomania.

Pavlov approached the analysis of sleep and similar states from an entirely original angle. He was able to bring the bright light of science to bear on this obscure field and to convert this confused labyrinth, which has served as a refuge for all sorts of metaphysics, into a highway along which all can travel.

He determined in a genuinely scientific fashion to refer even the pathology of sleep, all those complicated cases of the intervention of the "unconscious" (a term very widely employed by psychoanalysts) to the physiology of the actively functioning brain, *i.e.* to explain by the study of sleep many previously incomprehensible facts in regard to our waking condition, and in regard to "everyday life."

In all these complicated cases he set out, of course, from an analysis of the most simple facts. He always attempted to resolve complex phenomena into their simple elements, and only afterwards proceeded to a synthesis, to an explanation of the more confused phenomena, mainly of a clinical nature.

The most simple phenomenon, but one which enabled him to penetrate deeply into the mechanism of the origin of sleep, is the so-called *extinction* of conditioned reflexes. We have already mentioned this in examining the most important feature of the activity of the cerebral cortex, viz. its capacity for breaking elaborated cerebral connections or associations.

Let us recall that conditioned reflexes were called *temporary* connections precisely because, when they are no longer required, e.g. on any alteration of the external environment (and such alteration of the relations between a conditioned and unconditioned reflex are of frequent occurrence in the normal life of an animal), the corresponding cerebral connection loses its strength, that is to say it may be broken for a long time, or even altogether cease to exist.

The following is a good example of the extinction of a reflex. It is taken by us from the course with demonstrations given by Pavlov in 1924, that forms the foundation for his *Lectures on the Work of the Cerebral Hemispheres*.¹

For demonstration experiments on the extinction of reflexes, we used the laboratory dog "Prima" that had been studied for a number of years. The stimulus was the rhythmical ticking of a metronome, 104 ticks per minute. The usual size of the salivary

¹ Leningrad-Moscow, 1927, p. 54 (Russian).

reaction in this dog, thanks to prolonged preceding work, was equivalent to 10 drops for 30 seconds of isolated action of the metronome, the first drop always appearing 3-4 seconds after the metronome had been set going (the latent period). These two numerical indicators which form the basis for characterizing any conditioned reflex were also given by our dog on the occasion of the demonstration in the lecture hall of the Military Medical Academy.

For producing extinction of the reflex, the difference compared with the ordinary experiment is that after the regular thirty seconds the dog is *not given food*. This causes a gradual change in the magnitude of the conditioned reflex. In this particular case, on a test with the metronome after two minutes, the dog gave only seven drops of saliva after thirty seconds; the latent period had increased to seven seconds, thereby once again emphasizing the weakening of the connection between the cortical cells involved (the conditioned and unconditioned reflex centres).

Thereafter every two minutes (it has been shown by B.P. Babkin that regularity is of great importance here) the conditioned stimulus, the metronome, was again set going. We now obtained at first eight and then five drops, *i.e.* a result half that at the beginning.

In order to set out these data more clearly we give the whole record of the experiment in the usual form adopted in Pavlov's laboratory (see Table, p. 103).

What does this record show? It shows that those who expected a rapid breakdown of the conditioned connection were disappointed; although the metronome was not followed by giving food, the effect as regards salivary secretion only diminished

Record of Experiment

Start of Stimulation.	Stimulus.	Period of Isolated Action.	Salivary Reaction (Drops).	Latent Period (Sec.).
0 min.	Metronome	30 sec.	10	3
2 "	"	"	7	7
4 "	"	"	8	5
6 "	"	"	5	4
8 "	"	(Movement among the audience) 30 sec.	7	5
10 "	"	"	4	9
12 "	"	"	3	13

gradually, as if involuntarily giving way to our "pressure." For a moment, under the influence of the movement among the audience, it even increased again. Finally, however, at the seventh time, the salivary secretion was reduced to three drops with a comparatively long latent period (13 seconds).

The notes appended to the experiment state that the dog obviously found it difficult to tolerate the proceedings. It was unquiet, kept looking round, etc. Hence, for this dog and in this series of experiments at least, the "art of forgetting" proved no easier than the art of remembering.

In his work Pavlov more than once emphasized the important *physiological* meaning of the act of forgetting or, what is the same thing, the phenomenon of the breakdown of a temporary connection. It would in fact be biologically impermissible for the metronome, which had previously possessed a close connection with eating and which had ceased to be a signal for it, to continue to evoke the corresponding reflex. If a link which had once been established were to remain for ever

coupled up, it would be a burden for the brain and in no way lighten its work. In this experiment we saw how the animal before our eyes gradually broke with its former habit of reacting to the metronome as to food. In all such cases the rapidity with which the rupture of the connection concerned takes place depends on three basic factors:

(1) On the physical strength of the stimulus and the degree of previous training of the animal, *i.e.* on the number of times the metronome was associated with the *unconditioned* stimulus (eating).

(2) On the type of nervous system of the animal, that is to say on the individual characteristics of its brain.

(3) On the circumstances under which the extinction took place, in this particular case the behaviour of the audience.

We saw that a very slight alteration of the conditions, such as a slight movement among the audience, coinciding with the fifth repetition of the reflex in course of extinction, perceptibly revived it, although not for long.

Pavlov always attached enormous importance to this circumstance, *i.e.* the revival of a reflex during extinction, and he described it under the term of *disinhibition*. Pavlov frequently dealt on the meaning of this factor, the *removal* of inhibition by means of action from outside, and in the latest period of his work he connected it with the relative *weakness* of the accidental stimulus (in this case the slight noise among the audience) which "irradiated" over the mass of the cerebral cortex, removing the state of inhibition produced by our means of extinction.

We encounter here for the first time the factor of

the strength of stimulation, which is destined to occupy a very prominent place in the further exposition of the problem of inhibition and sleep.

Let us turn our attention to some extremely important conclusions to be drawn from a more careful analysis of the above-described experiment on extinction.

In the first place, it is found that even if the extinction of the reflex to the metronome is continued until the reflex is zero, after the lapse of a certain time, e.g. on the next day, the reflex may have regained its former magnitude, *i.e.* ten drops of saliva after thirty seconds of the isolated action of the metronome. Consequently, the phenomenon of extinction of a reflex, like that of its formation, exhibits a *temporary* character; on the expiry of a definite period the conditioned connection established in the brain regains its previous significance. It is possible, of course, to obtain a complete annihilation of the elaborated reflex by means of systematic extinction carried on for many days, but this requires no little labour.

In the second place, we have the circumstance that if the conditioned stimulus is even only rarely reinforced by the corresponding unconditioned stimulus (eating), work may be carried on for producing extinction throughout months and years, as was shown by Kogan, and nevertheless the conditioned reflex will be exhibited every day in unaltered strength at least during the first part of the period. In this case the extinction *curve* of the salivary reflex falls at first more sharply and afterwards flattens out, *i.e.* it shows a typical *logarithmic* form, like the curves familiar from the experiments of the psychophysicists Weber and Fechner.

It is interesting to notice that exactly similar curves were obtained by the psychologist Ebbinghaus in his experiments with human beings on the forgetting of *meaningless syllables* previously learnt by heart.

In these well-known experiments, Ebbinghaus used as a measure of forgetting the number of syllables that were *still retained* in the memory (the time taken was measured in days), while in Pavlov's experiments the indicator was the number of drops of saliva, one much more convenient for measuring the remaining reaction.

The coincidence in the results of these two researches is not accidental; it provides one of the clearest confirmations of the close relation between some fields of physiology and psychology. At the same time, however, it demonstrates that the physiological method in this case goes deeper, for it not only establishes the objective facts but also penetrates into the internal mechanism responsible for them, connecting them with the strength of particular processes and with the dynamics of change in time.

Thus, for instance, Ebbinghaus does not mention at all that the approach of complete absence of effect in the subject experimented on, after a short period of inquietude which is also very characteristic, is marked by drowsiness, tiredness and immobility, passing into a general state of sleep, sometimes very profound.

We find, therefore, at least in animals, that on the summation of inhibition produced by the rupture of an earlier established nervous connection, the inhibition is, thanks to the repetition, gradually trans-

formed into sleep. Later we shall see that the same thing holds good in the case of human beings when ill. The re-establishment of a conditioned reflex, the revival of a temporary connection, its disinhibition, is always accompanied by the abolition of sleep, by the restoration of the waking state in the animal.

From this it is not far to the conclusion actually made by Pavlov in a special memoir presented to the Academy of Sciences in 1922 after twenty years of detailed research into these kinds of phenomena. The conclusion there drawn is that sleep and internal inhibition are phenomena of the same nature. Inhibition arising as a result of the rupture of a conditioned reflex and inhibition arising with the onset of normal physiological sleep are *essentially one and the same process*.

This conclusion, classic in its simplicity, at which Pavlov arrived, however, not at one step but through a series of intermediate hypotheses concerning the characteristics of the sleeping state, has proved of benefit both to the physiological theory of sleep¹ and to practical work with conditioned reflexes.

It has now become possible not only to make the animal sleep whenever desired by using the simplest physiological means, in particular by extinction, but also to measure the *depth of sleep* and to retard the course of its development during any of its phases and for any period. It is this last circumstance that has led physiologists to the analysis of hypnosis, suggestion and finally somnambulism and lethargy, of which further mention will be made later when an account is given of a number of supplementary

¹ A number of other theories of sleep have been put forward, *e.g.* the chemical theory, the histological theory, etc.

experiments connected with the features of other aspects of internal inhibition.

For the time being, let us turn our attention to the last circumstance noted in the above-described experiment in the lecture hall. It was in this demonstration experiment that we first succeeded in noting (as was afterwards confirmed by a number of other investigators) that, even when the conditioned stimulus remained at full and constant strength and the circumstances of the experiment were maintained unchanged, characteristic variations sometimes occurred in the magnitude of the conditioned reflex and latent period, these variations having a marked *rhythmical* character. It was found that every conditioned reflex (although not in all animals but only in those of a so-called evenly balanced and inert type) is extinguished in an undulatory fashion, gradually decreasing in size until reduced to zero. But even after the zero point has been reached it is still possible for repeated isolated actions of the reflex to occur, as it were temporary and independent revivals of it (see Fig. 13).

As the result of numerous experiments, we became convinced that the nervous process in the cerebral cortex can be characterized as *rhythmical* or oscillatory. It was found to be characterized by a gradual *extinction* just as in the case of certain physico-chemical and electrical processes of oscillatory character; with this difference, however, that the phenomena of extinction in the brain are of a much more complex physico-chemical character, and may last for months and years, or even decades.

This rhythm apparently forms the basis for the physiological mechanism of certain phenomena of

memory and the obtrusive reproduction of what has been once seen. This phenomenon has also a close relation to the mechanism of origin of *dreams* which, in spite of all their strangeness, frequently obey certain of the laws of combination of trace reflexes in process of extinction, as do all phenomena occurring in the brain, depending on their intensity.

Let us take the frequently encountered phenom-

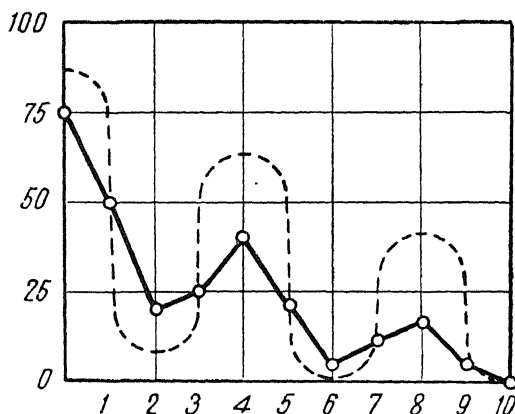


FIG. 13

Diagram of the extinction of a conditioned reflex. Abscissæ represent successive trials of the reflex, ordinates the size of the response (explanation given in text).

enon of waking at a previously fixed time. One goes to sleep after setting the alarm clock at a definite time. Suddenly one wakes up in spite of the fact that in general one sleeps soundly and calmly. On looking at the clock it is found that it is almost on the point of striking; in another minute the alarm sounds.

There is no doubt that it will seem to many people as if they had some clock mechanism inside their

bodies. Experiments of Feokritova on sleep have demonstrated that during a period of complete rest in an animal the nervous system takes *better* account of the passage of time than it does during a period of activity. In the waking state we commit many errors in calculating time (*e.g. illusions as to duration*). There is no doubt, however, that our waking regulatory activity is accompanied by an exact calculation of time. The rhythm of the higher processes is the basis for the calculation of time; it is the most complicated or, if you will, the most fundamental "clock" mechanism at our disposal.

All these far-reaching conclusions, as far as they concern the interpretation of behaviour, are based on the study of processes taking place in *only one* complex of cortical nerve cells, connected let us say with the reflex to the metronome reinforced by eating. We have now to acquaint ourselves with a number of laws governing the activity of *numerous* cells. These laws are bound up with new discoveries regarding the activity of various cells concerned in the functioning of the sense organs.

THE ANALYSIS OF THE SURROUNDING WORLD AND THE ROLE OF THE SENSE ORGANS IN HIGHER NERVOUS ACTIVITY

What are the limits to the capacity of an animal in analysing objects and phenomena of the surrounding world? This question is of great importance in the study of the majority of known forms of behaviour in animals, both lower and higher, and also in man. The answer to this question is important both for our idea of the methods of the struggle for existence on

the part of a particular animal and for curing various defects of vision, hearing, etc.

While in the case of an adult healthy human being it is sufficient merely to ask whether he can distinguish between two stimuli put before him, *e.g.* red and green colours, such a method is of course entirely inapplicable in the case of the colour-blind or of infants, not to speak of animals. Consequently, such eminent investigators as Helmholtz and his follower Wundt who founded physiological psychology, went to great pains to find a physical and psychological basis for the question of objective definition of the limits of analysis of the surrounding world, at any rate in man. The behaviourists continued their work and collected a vast mass of data on the activity of the sense organs of animals of various degrees of development.

No one, however, has penetrated so deeply as Pavlov into the internal physiological mechanism of analysis, or has succeeded so well in separating the roles of the peripheral and central parts of the nervous system in any act of behaviour. No one has succeeded with such accuracy in establishing the laws of analysis and synthesis of the surrounding world as did Pavlov, who employed for this purpose his method of conditioned salivary reflexes. It should be noted also that Pavlov had at his disposal the entire resources of contemporary technique and especially of electrical and other apparatus, such as not every country can afford to give but which is of the utmost importance in putting the environment of the animal at the disposal of the experimenter.

Pavlov's laboratory in the Institute of Experimental Medicine on Aptekarsky Island was the scene

of a unique competition between the latest achievements of modern physics and chemistry on the one hand, and the remarkable perfection of the receptor organs of an animal (the dog) on the other. The years 1907-24 were a period during which the determination of the limits of analysis and the laws governing the activity of the sense organs played a decisive part in Pavlov's work.

Let us begin with an organ which it might seem has already been adequately studied, viz. the eye. How far can a dog distinguish between the intensities of light reflected from screens of the same colour differing only in the degree of light absorption (see Table, Fig. 14)? In our experiments on this subject, made in 1913, we selected screen No. 50 (black) as the active stimulus, *i.e.* we always accompanied its appearance, after 30 seconds, by giving the dog meat-biscuit powder. A conditioned reflex was established with a strength of 12-15 drops of saliva.

We then began sometimes to put before the dog screen No. 1 (white), which, of course, was never accompanied by food. At the beginning we obtained the conditioned reflex even to this apparently so distinct stimulus. The explanation of this will be given below. After some weeks, when the dog already sharply differentiated No. 50 from No. 1, we put before it screen No. 5, which again at first produced the reaction of secretion of saliva. By repetition the latter reaction was abolished.

Screen No. 5 was followed by No. 10, and then by No. 25 and No. 35. Each time the whole history was repeated, but it is of interest to note that although the stimuli began to approximate more and more closely to one another, the dog found less and less

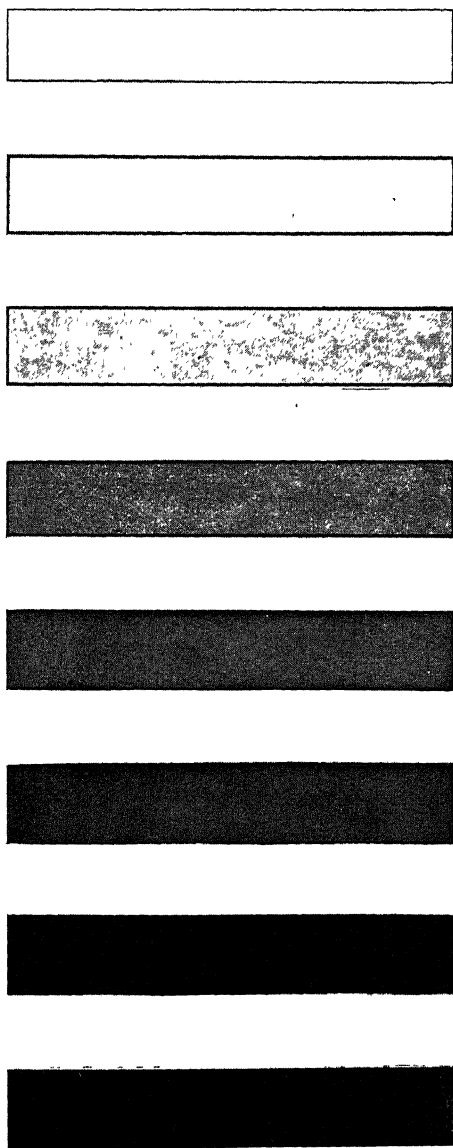


FIG. 14. Models of light screens of different reflecting power. From Y. Frolov's work on the limits of discrimination of the intensity of light by the method of conditioned reflexes

difficulty in distinguishing between them—obviously the effect of the “training” of the higher centres. This continued until screen No. 47, and especially No. 48, which was only distinguished with much trouble, *i.e.* after a large number of trials. With this screen the inactive stimulus had to be shown more than thirty times.

Finally, the day arrived (January 30th, 1914) when on employing first of all screen No. 49 we received a response only *half* the effect of No. 50, *i.e.* we obtained a clear *differentiation* of the stimuli at a separation of eight minutes. It should be emphasized that the intensities of light reflected from these screens were distinguished from one another by only a very small fraction ($\cdot 09$) of a candle-power, and to the human eye were absolutely *indistinguishable* !

The following is the experimental record of this day:

Time Stimulus Applied.	Character of Stimulus.	Serial No.	Salivary Reaction (Drops).	Latent Period (Sec.).	Remarks.
3.13 P.M.	No. 50	450	10	6	(I. P. Pavlov was present during the experiment.)
4.01 „	„ 50	451	12	5	
4.09 „	„ 49	I	6	12	

We have dwelt on this series of experiments on light intensity only because it convincingly demonstrates the advantages of objective study of the analysing activity of the dog, particularly as compared with the method of self-observation. It is also possible to note how simple this method of investigation is; although, in contradistinction

to the subjective methods employed, for instance, in psychology, it demands great expenditure of time because of the necessity of making the process of training a gradual one.

Nor is this, of course, the only information that can be drawn from the study of conditioned reflexes with the eye. Using the same means of investigation, L. A. Orbeli succeeded in proving as long ago as 1905 that the vast majority of dogs do not distinguish between stimuli so far apart in wave length as red and green colours. In spite of thousands of experiments carried out by him, his dogs continually confused these two colours, *i.e.* they proved to be physiologically colour-blind.

Hence the modern dog, the descendant of night marauders like the wolf and jackal, evidently does not possess any biological basis for colour vision. Although half a million years have passed since the dog altered its mode of life and ceased to be a free inhabitant of forests, nevertheless this period has proved insufficient for it to acquire the daylight vision possessed not only by man but also by certain insects. Thus, as was recently shown by Fritsch, who also used the method of conditioned reflexes, bees in gathering honey from flowers display a remarkable capacity to distinguish between complicated coloured objects and shades of colours.

It turns out, therefore, that the organ of vision of the closest friend of man in the animal world, *viz.* the dog, has an essential defect from our point of view!

The reader may ask how it is that the dog, if it possesses no colour vision, can react to the surrounding environment. In exactly the same way, it may be

replied, as human beings distinguish objects and events shown in a cinema (before the advent of *coloured* films), *i.e.* by being guided solely by differences in the *intensity* of the light; it is just this latter capacity that, as we have seen, is extremely well developed in the dog. Dogs are guided also by form and the movement of objects in space. Pavlov remarks:

“It can hardly be contested that actually all problems in the sphere of the so-called physiology of the sense organs can be analysed in animals by the aid of conditioned reflexes. Are not even Helmholtz’s ‘unconscious inferences’ in his *Physiological Optics* genuine conditioned reflexes?”

Let us recall that “unconscious inference” is the term given by Helmholtz to acts taking place in the nervous system, such as a child’s correction of its visual perceptions, concerning, for instance, the nearness of the moon’s disc, by means of motor impulses (testing the distance with the hand, which proves to the child that the moon is too far away to be grasped).

We see that Pavlov went much deeper than Helmholtz into the analysis of the sense organs, for he employed as the object of experiment an animal (the dog) to which the terms “consciousness” and “inference” are altogether inapplicable.

Moreover, Pavlov showed that all analysis of the external world comprises two sharply delimited stages, each of which possesses its own physiological characteristics. He remarks:

“The primary basis for analysis is provided by the peripheral endings of the afferent nerves of the organism, each of which is constructed in a special manner for transforming a particular form of energy

(both within and without the organism) during the process of nervous stimulation.”¹

Hence the primary and very important, though still very crude, analysis of stimuli impinging on us from outside takes place at the periphery.

It is true that the sense organs at the periphery do act as special analysers, as Helmholtz thought. But the real, highly delicate and perfected analysers (or more exactly their central endings) are referred by Pavlov to the cortex of the cerebral hemispheres, which, as we have seen, is also the seat of formation of the corresponding conditioned reflexes to light, sound, odour, etc., and the seat of their differentiation.

It is the complexly interwoven cortical cells, which possess the most delicate histological structure and the highest physico-chemical organization known to us in the whole organic world, that are the seat of the exact analysis of stimuli that most of all interest us, such as the timbre and intervals of sound, linear and aerial perspective and so on. It is here that the obtrusive illusions of movement that cause us to imagine that the sun moves while the earth stands still, etc., begin to be combated. The same thing applies to the synthesis of sounds, colours, etc. No musician or other artist would be able to perceive anything or to communicate anything to others if he possessed *only* the *peripheral* parts of the analysers. Consequently, “unconscious inference” in Helmholtz’s sense of the term is a conditioned reflex which is governed by the firm laws of the functioning of the cortex, and therefore the higher acts connected with

¹ Pavlov, *Lectures on the Work of the Cerebral Hemispheres*, 1927 (Russian).

vision must be studied, not in the field of optics, but in the field of the higher nervous activity of man.

Let us return, however, to our laboratory animal, the dog. We have remarked that the study of the analysers by the aid of conditioned reflexes in conjunction with the method of *extirpation* of particular parts of the cortex, enabled Pavlov to introduce a radical revision of the "map" of cerebral functions in the dog, where until recently, as in geographical maps of the Arctic, there were only too many "blank spaces."

Some psychologists connected these gaps with the presence in the dog of *higher* associative centres. Pavlov approached this problem with an entirely different criterion. After elaborating a series of conditioned salivary reflexes and differentiating them from one another with just the degree of exactness required, he performed under narcosis the operation of removing definite parts of the cortex, excising the grey matter by means of a sharp scalpel within previously fixed limits that varied in different experiments according to the plan decided on.

The dogs bore these operations comparatively easily, and within two or three days they could be again put in the stand and were capable of taking food and yielding saliva in the former quantities (unconditioned reflexes). As regards the conditioned reflexes, these as a rule *disappeared*, although not always to the same extent in each case.

By means of the *extent* of derangement of higher nervous activity, it was possible to make an accurate estimate of the extent of damage caused to the particular analyser, *i.e.* to *localize* the corresponding reflexes in the cerebral cortex (see Fig. 10).

In putting together the results of these experiments, it was found that each of the analysers has a very wide distribution over the whole "map" of the cortex. For instance, the auditory analyser is represented in both the frontal and occipital parts of the brain; it is sufficient to leave untouched only a small fragment of the grey matter of the cortex, and by its means the dog could distinguish loud noises from other sounds.

The higher centre of analysis of sounds, however, or the "nucleus of the sound analyser," as Pavlov called it, is situated in the *temporal* region a little way behind the so-called gyri of Sylvius.

We have mentioned that the functions of the damaged portions of the cortex are observed to be restored after the operation. This fact is confirmed too by clinical observations of cerebral hæmorrhages in man. In animals, however, this vicariation of functions on the part of neighbouring cells takes place with striking rapidity and completeness.

It was, naturally, not at all to be expected that this phenomenon of vicariation of functions, so well known to us from the pathology of other organs, such as the kidney and lungs, would be encountered in the cerebral cortex where we are confronted with such delicately differentiated anatomical structures and physiological processes. Nevertheless, Pavlov's experiments referred to are an indisputable fact. It is perhaps just this rapid possibility of the restoration of cortical functions, together with the exactness of their analysing capacity, that gives the higher animals their enormous advantage in the struggle for existence.

Particularly valuable data for determining the

general limits of adaptability of the nerve centres in regard to stimulation were obtained by experiments with conditioned reflexes, using the dog's *ear* as the seat of stimulation. It was found that the great majority of dogs possess so-called *absolute hearing*, i.e. they are capable of reacting correctly to any sound and to distinguish it from another which we have made active or non-active. Moreover, they react without preliminary comparison with other sounds, in contrast to what is required by the majority of human beings. In other words, in regard to the musical scale, dogs are found to have an *absolute sense of pitch*, a phenomenon not so frequently encountered even among very good musicians.

It was discovered further, in the experiments of Tikhomirov, that dogs distinguish excellently between different intensities of sound, just as was described above in the case of analysis of intensities of illumination. Finally, the dog can analyse accurately the timbre of a sound (the character and number of over-tones), and differentiates an ascending scale from a descending one with perfect appreciation of sound intervals. For instance, it was shown that a metronome frequency of 100 ticks per minute could be made an active stimulus, while a frequency of 104 or 98 ticks proved inactive (experiments of Usiyevich).

Most instructive of all are the experiments of Burmakin on the analysis of sounds inaudible to the human ear, which are nevertheless excellently heard by dogs and can be exactly differentiated. For producing these sounds in the laboratory, at first a Galton whistle was used and later an apparatus for producing *pure tones*.

These experiments were marked by a high degree of objectivity and precision. They produced a marked impression on all those who were present when they were performed. The visitor enters a chamber isolated from all accidental sounds or other stimuli; the experimenter switches on the apparatus that is known to produce a particular inaudible sound. In the room, however, the same tense silence is preserved; nothing can be heard however much one strains one's attention. The only "reacting" objects to the sound in this case are the dog's *ears and salivary glands*.

A few seconds after switching on the apparatus, the animal begins to move about in the stand; it becomes on the alert and saliva begins to flow—the conditioned reflex is fully exhibited. After a certain time, a different inaudible sound is switched on, an inactive one this time, and no reaction takes place.

As regards the sense of *smell*, practical life appears to have gone in advance of experiment. Indeed, what an advanced technique of "smell measurement" would have to be created in order to judge the activity of the olfactory organ in a dog, which without any special apparatus is able to distinguish the smell left by the boots of his master who has gone along a certain route some hours before! Such is the situation in regard to the olfactory sense of the domestic dog, the perfection and accuracy of which cannot be attained by any apparatus.

If the animal's sense of smell is subjected to special training, as in the case of hunting and other dogs, remarkable effects are obtained, such as the discovery of traces of game, or the hunting down of a criminal merely by allowing the dog to smell a

piece of clothing or other object left behind by him, although the trail may be several days old.

Experiments performed by the method of conditioned salivary reflexes have shown that the dog easily differentiates between such odours as those of amyl alcohol, camphor, ambergris, vanilla, turpentine, mustard and many other substances, taken separately or in a mixture and in circumstances where practically no preliminary training is imparted (Kudrin).

It should not be thought, however, that the analysis that can be performed by even the most



FIG. 15

Exciter screens for determining the limits of a dog's discrimination of the shapes of geometrical figures (from the work of Schenger-Krestnikova).

well-developed "distance receptors" of the dog, *i.e.* the eye, ear and nose, is unlimited and requires no exertion. The exertion required is not inconsiderable. Consider, for example, the experiments of the ophthalmologist Shenger, a pupil of Pavlov's who set himself the task of determining the extent to which a dog could distinguish between different plane geometrical figures, a problem which had also previously occupied the attention not unsuccessfully of many behaviourists. The basis for the experiment consisted in taking a *circle* which was always reinforced by giving the animal food, and afterwards differentiating it from a series of ellipses, at first markedly different from the circle but gradually approaching closer to it (see Fig. 15).

It should be remarked that these experiments were performed on a dog that had previously been well trained in our experiments with different intensities of light. In the beginning everything went well; but when the dog was faced with the task of differentiating the last ellipse, the one least distinguished from the basic figure of the circle, the dog was literally transformed. Every time that this ellipse was presented, the dog, not being able to distinguish the active stimulus from the inactive, began to become restless, to whine and to attempt to jump down from the stand. Its whole behaviour expressed as it were a refusal to solve the problem presented to it, and indicated with the means available to it the *difficulty* and even *pain* involved in the position in which it was placed by the insistent experimenter.

We specially emphasize the circumstances of this experiment, because when it took place in 1915 it provided the first example of so-called *rupture* of higher nervous activity and the first formation of an experimental *neurosis*, a phenomenon which during the following ten years engaged the constant attention of I. P. Pavlov.

Although not specially dealing with human beings in this connection, Pavlov also gives an indirect answer to the question as to what constitutes the distinguishing features and advantages of the analysing activity of man as compared with the higher animals.

The point is this: if an animal such as the dog possesses absolute hearing and sense of smell, if it can analyse the intensity of light with such extreme exactitude, and further possesses such exact means of orientating itself in space, then what constitutes

the evident pre-eminence of man, that which makes him master of the earth and ruler over all other animals, the arbiter of their destinies?

Leaving on one side for the time being the dispute as to "abstract" thinking in man and animals, which will be dealt with later, Pavlov gives the following answer to the above question. Man's advantage consists in the fact that he easily analyses complex, *synthetic* stimuli, and that he very early, even during childhood, begins to analyse such complexes. We may remark that all speech consists of complexes of basic sounds occurring in continually changing sequences.

A dog in which A. Ivanov-Smolensky had elaborated a stable conditioned reflex to the following combination of sounds, "noise—high tone—low tone (sharply distinguished from the former)—bell," had enormous difficulty in differentiating this set of excitants from another set where the two middle terms were given in the reverse order, *i.e.* first the low tone and then the high one.

A human being, on the other hand, even if not musical, would distinguish these two simple combinations on the very first hearing. Hence the essence of the matter is that in the brain of the dog these four components are too closely bound up together owing to their general basis (noise). To delimit their role in the complex is something which is already a matter not of elementary but of *higher* analysis, in which the leading role is definitely transferred from the sense organs, which are sometimes even better developed in animals than in man, to the cortical cells, to the numerous connections between these cells (which are, of course, much

more richly developed in man than in animals), and finally, in particular, to the special features of the *spread* of the neurocerebral process, a subject that will be dealt with below.

Consequently, in speaking of the analysis of external stimuli, and in nature these occur for the most part in the form of complexes, it is necessary always to keep their *synthesis* in mind. For the same reason the cortical organs, of which mention has been made above, must be termed not merely analysers but rather organs of *analysis and synthesis*.

TRACE CONDITIONED REFLEXES

The conception of traces of stimulation, showing themselves in the form of so-called after-effects, is familiar from general nervous physiology (Sechenov). Even brief stimulation of a nerve fibre often has the result that, on cessation of the stimulus, the effect evoked by it, *e.g.* the slowing of the heart rate on stimulation of the vagus nerve, does not cease at once but dies away gradually. This signifies that the physico-chemical changes produced at the termination of the nerve fibre during its stimulation, *e.g.* by an electric current, still have their effect during a certain interval of time after stimulation has ceased.

In 1909, Pimenov succeeded in forming a special conditioned reflex by introducing the unconditioned stimulus after the cessation of action of the conditioned stimulus. It was found possible to make a definite pause between the cessation of the action of the conditioned stimulus and the beginning of the action of the unconditioned stimulus, and yet

the conditioned reflex was established. Such a reflex was rightly called a *trace conditioned reflex*. It was found that such reflexes obey the same laws that hold good for ordinary ("immediate") conditioned reflexes.

Later workers, however, pointed out distinguishing features between these two forms of reflex. It was shown that trace reflexes are formed with great difficulty, *i.e.* they require a large number of reinforcements by the unconditioned stimulus; in addition, on changing a direct reflex into a trace reflex (*i.e.* during the first tests with the introduction of a pause) it was observed that there was a phase in which the elaborated reflex to the given stimulus disappeared and the animal might even fall into a state of sleep. Later this phenomenon became weaker, but subsequently, when the conditioned trace reflex appeared fully established, in the first place, it remained of smaller magnitude and, in the second place, it was distinguished by lesser stability. The most rational method of forming trace reflexes is that of transition from "direct" reflexes with gradual prolongation of the pause.

The above facts, taken as a whole, show that in our experiments with trace conditioned reflexes, some new factor takes part that is absent in experiments with direct reflexes.

This factor is time. Physiologically, the period of the *pause* cannot be regarded as empty. My experiments have shown that during this period a number of interesting processes take place in the analyser concerned, processes which determine the undulatory character of extinction of excitation in the central nervous system.

There is nothing strange in the supposition that time can be an exciting agent, that reaction to time is a very important reaction in all animals from the lowest to the highest. And while the physiology of the eye and of the skin-muscle receptor surfaces has shown the importance of space measurement for the organism, for no vital adaptive action can proceed without involving measurement of distance, the physiology of conditioned reflexes has undoubtedly shown that the reaction to time (the estimation of time) is an equally important if not even more important part of the adaptive activity of the animal.

In all movements, beginning with the movement of a mollusc that opens its shell at the time of flood-tide and continues to act in this way even in the aquarium, and ending with the movements of an acrobat performing on a trapeze, living beings have constantly to take time into account in fulfilling their characteristic functions.

Exact experiments for studying the sense of time by the method of salivary conditioned reflexes have shown that if a dog is fed at the end of equal intervals of time, *e.g.* after thirty minutes, then with practice it is possible to reach a position in which saliva begins to be secreted as soon as the hand of a stop-watch indicates $29\frac{1}{2}$ minutes after the last time the animal was fed.

To a considerable extent, the same thing holds good for man also, although in this respect very great individual differences are observed. It should be added that those professions which demand the highest concentration of attention give the highest percentage of accurate estimations of time.

THE SPREAD OF THE TWO NERVOUS PROCESSES OF EXCITATION AND INHIBITION. IRRADIATION AND CONCENTRATION IN THE CEREBRAL CORTEX

We must warn the reader that this important chapter of the physiology of higher nervous activity is one that is difficult for non-specialists to understand, the more so as it deals with phenomena occurring in the brain that in point of fact have never been *directly* seen by anyone and can be judged only by indirect signs, *i.e.* by a specially established connection between the appropriate cortical cells and the reaction of the salivary gland. Nevertheless, it may be recalled that an astronomer who studies the composition of remote stars makes use for this purpose of a spectroscope from the lenses of which he demands only that they should possess a constant index of refraction.

We consider that a detailed account of the facts now to be described concerning the spread of nervous processes in the cortex is especially important and necessary because it and it alone provides the basis for all our further conclusions on inhibition, sleep and related states.

Our account can be based on the preliminary information given by general nervous physiology concerning the spread of the fundamental nervous processes in the lower centres of the central nervous system.

It must, however, be clear that in the cerebral cortex the space-time changes of the processes of excitation and inhibition proceed under much more complicated conditions and demand much more concentrated attention than is required for understand-

ing, for instance, the experiments of Sherrington, Magnus, etc.

Pavlov had the great advantage that when he approached the analysis of these complex phenomena he already possessed a knowledge not of one but of two processes that occur in the cerebral cortex, viz. he had studied not only excitation but also the process of active inhibition. The majority of scientists working on phenomena of irradiation and contrast (*e.g.* in analysing so-called optical illusions) have for the most part had to deal with a process of excitation that changes so rapidly that it is extremely difficult to express it in space-time terms. The process of inhibition, however, is much slower, and research into it can be conducted systematically and without undue hurry.

N. Krasnogorsky, who was the first to trace the spread of this nervous process (inhibition) in the cortex, was in the fortunate position of working with a receptor in which excitation could be produced by means of some light apparatus attached to the surface of the skin itself, the latter being previously prepared by shaving (see Fig. 16). The apparatus was set going at first by hand but afterwards automatically.

It should also be noted here that before the experiments with conditioned reflexes, the skin—this powerful receptor of mechanical and heat stimulation—had been to a certain extent a neglected field. The psychophysiologists performed experiments with the skin to a much less extent than with the eye or ear. This is, of course, understandable; we owe all the main foundations of our wealth of knowledge of the external world to the “higher” sense organs. Moreover, the physiologists themselves were at first

unwilling to concern themselves with the skin receptors because work with weak skin stimuli very frequently, more frequently than in other cases, led to drowsiness and sleep in the animal—a circumstance that subsequently was of great importance in the elucidation of the mechanism of sleep.

Krasnogorsky, who established definite reflexes in the skin analyser and differentiated them, became convinced that inhibition when once produced spreads or irradiates, taking hold of ever new portions of the brain. This spread can be timed even by using an ordinary watch since it proceeds very slowly, especially in some individuals.

First of all, however, let us say a few words as to what irradiation is, understood not in the physical but in the physiological sense.

Let us suppose that you look at and compare two squares, a black one on a white background and a white one on a black background (see Fig. 17). With sufficiently strong illumination, the white one will appear larger than the black one to the vast majority of people, although the squares are abso-

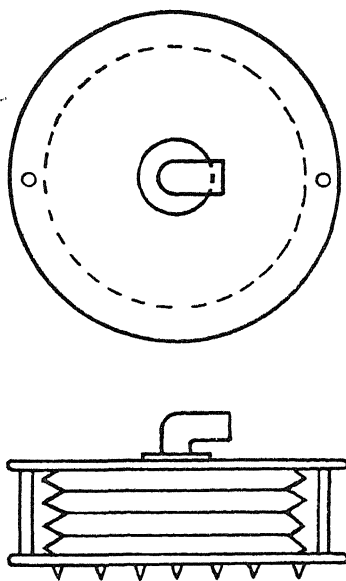


FIG. 16

Instrument for the excitation of different sections of a dog's skin for the creation of a conditioned reflex.

lutely identical in size. This illusion, known from the time of Goethe (1810), depends on the fact that the white square produces a greater excitation of the retina, spreading to neighbouring elements of the latter and thus producing the sensation of *radiance*. The result is a marked increase of the figure in four directions constituting an irradiation of the white figure in the field of vision.

The same thing takes place also in the brain, with

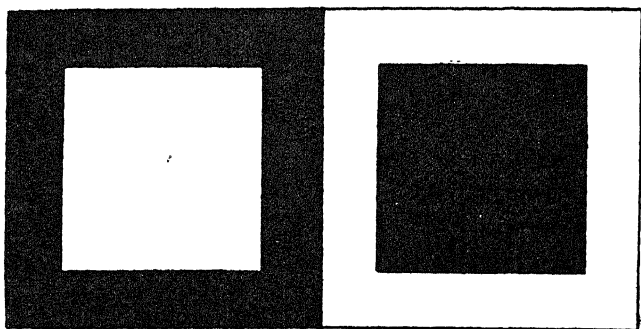


FIG. 17

The irradiation of excitation in the retina of the eye (explanation given in text).

the difference only that the inhibited spot, corresponding to a single point of the analyser, may also emit "rays" and apparently increase in size, *i.e.* irradiate. The skin analyser is especially suitable for such experiments for another reason also, *viz.* that it presents as it were a projection of the brain localization enlarged to tremendous dimensions; it is possible to follow on it, as on the screen of a television, the source from which the process comes, in what direction it proceeds and how long it lasts, etc.

Krasnogorsky, and other scientists who investigated the phenomena of irradiation and concentra-

tion, had to devote considerable periods of time to their experiments and had to exercise great patience and also choose very good animals. Why is this?

In their experiments they were concerned with elaborating in the dog a series of reflexes to stimulation of various places on the skin at a known distance apart, 5-10-20-25 cm., a work requiring one or two months. Following this it was necessary to equalize the size of all these reflexes, whatever the place chosen on the skin, and also the size of the corresponding latent periods, and then to put one of the stimulated places (more correctly, of course, the corresponding point in the cortex) into a state of inhibition, that is to say to differentiate it from the remainder by systematically leaving it without reinforcement and so extinguishing the reflex to stimulation of that point. This work required several months more. By increasing the number of such extinctions it was possible to graduate the intensity of the inhibition produced.

Finally, using five different stimulators and carrying through five corresponding series of experiments, it was possible to come to the basic experiments, viz. to find out what happens to the size of the conditioned reflex on experimenting at intervals of 1-2-3 minutes with the place nearest to the place of extinction, and then to do the same thing in relation to the next place in the series, and so on.

Without quoting the exact figures, and leaving out of account the individual peculiarities of the animal, it is possible to reduce the results of all these experiments lasting for many years to a single scheme such as is depicted in Fig. 18.

This state of inhibition, examined from the point

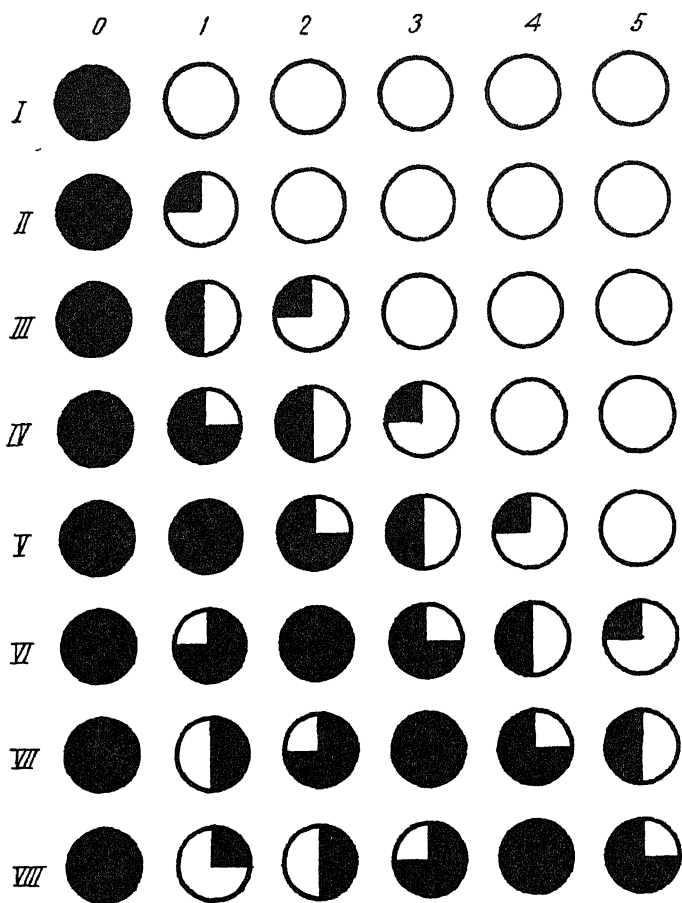


FIG. 18

Diagram of the process of irradiation of inhibition in the cortex of a dog. The Arabic numerals (the horizontal row) signify the numbers of the tested points on the dog's skin, No. 0 being the point at which inhibition had been established, and Nos. 1, 2, 3, . . . etc. being successively more remote from it. The Roman numerals (vertical row) signify the intervals elapsing from the moment when the inhibitory stimulus to point No. 0 ceased. The extent to which the various circles are shaded indicates the degree of inhibition of the response to stimulation of the corresponding points after the time intervals shown.

of view of time, is found to spread in an undulatory (circular) fashion embracing definite elements of the brain and leaving others unaffected. It might remotely be compared with the spreading of ripples on the smooth surface of water disturbed by throwing in a stone.

And just as such circular waves on reaching the edge of a pond are reflected and return to the centre (the original place of disturbance), so also the nervous process, if it does not encounter any resistance in its path, spreads to its furthest limits and then again begins to *concentrate* at its starting-point.

It is, however, by no means invariably the case that both these phenomena can be observed in such a schematically simple form as described here; the cerebral cortex is never in such an ideal state of rest. Nevertheless, the spatial irradiation of nervous processes in the cortex is an undoubted fact. As Pavlov showed in some of his latest experiments, the decisive factor in all these alterations of the process lies in the *strength* of the exciting agent, in this case the strength of the inhibiting agent, as well as in the *type* of higher nervous activity characterizing the individual animal.

The inhibition at the point of departure can be strengthened by repeating the inhibiting stimulus several times in succession. In such a case it can be shown that weak stimulation produces irradiation of the inhibition and sleep, while stimulation of average intensity produces concentration of the inhibition. In the case of strong and very strong inhibiting agents, other very characteristic relations are established which will be dealt with below.

It is interesting to find out what takes place in the brain when we deal with a process of excitation

and not of inhibition. Does such excitation spread out from the initial point and, if so, how rapidly does this process spread in time and space as compared with inhibition in the above experiments of Krasnogorsky?

The answer to this question was given in a dissertation by M. K. Petrova, who showed that the process of excitation also spreads through the substance of the cerebral cortex, but with much greater rapidity than the process of inhibition, and hence constitutes a much more difficult although just as instructive object for investigation by means of the method of conditioned reflexes.

With both weak and very strong stimulation at the point of departure, irradiation of the excitation takes place. In the second case, if looked at from the external aspect, there occurs what is called an *affective reaction*. It was such an irradiation of excitation that occurred at the beginning and end of the previously described experiments of Yerofeyeva with the electric current.

With stimuli of average strength, concentration of the excitation occurs. This state corresponds to the optimal state of functioning of the cortical cell. It is for this reason that, except for special cases, Pavlov's laboratory always employs stimuli of average strength: a metronome, electric bell, a dim flashlight, slight pain imparted to the skin, etc., although, as we shall see below, there are also gradations of strength among these stimuli.

We began our account of the spread of the two nervous processes by referring to the phenomenon of irradiation in the sphere of the sense organs, and we endeavoured by this example to make clear the

significance of the analogous phenomena occurring in the cerebral cortex. We shall conclude this section by referring to another well-known psychophysiological phenomenon, namely the part played by *contrast* in the activity of the external sense organs.

That grey, side by side with white, appears almost black, and that a very little joy after great distress appears to be happiness, has been known long enough from everyday experience. But the phenomenon of contrast is by no means restricted to such examples. Remote in comparison with near (speaking of such distances as those between the previously mentioned pieces of apparatus for stimulating the skin) appears to be still more remote. We can also convince ourselves of this by employing the very delicate technique of conditioned reflexes in studying so-called *nervous induction* in the cerebral cortex.

Physiological induction is, of course, different from physical induction. Positive induction, as observed in the nervous system, is manifested by the process of inhibition produced by us at one point of the skin analyser evoking the appearance of a process of opposite sign, *i.e.* excitation at another point of the same analyser.

[This phenomenon, it is true, is encountered for the most part only at the beginning of the process of differentiation and during the initial phase of the formation of inhibition. If, however, the training of differentiation is carried on for a longer period and the differentiation attains a high state of perfection, then no "contrast" appears on the subsequent application of the active stimulus. On the contrary there is even an inhibition of the conditioned reflexes following the inhibited stimulating agent.

The wealth of data obtained in this field of the study of conditioned reflexes obliges us to mention yet another form of the mutual relations of the nervous processes in the cortex, viz. so-called *negative induction*, a phenomenon which has no equivalent in psychology and no ready-prepared term, and consequently has hitherto been very little investigated.

In making mention of this in addition to the other phenomena we run the risk of overburdening the attention of the reader. But there is no help for it. Without dealing with this phenomenon of negative induction, our account of the theory of inhibition, as developed by Pavlov during the latest period of his work, would be incomplete.

Thus, there exists not only positive but also negative induction, occurring in certain circumstances when a process of excitation once called into being does not destroy, but instead strengthens, its "enemy," i.e. the inhibiting process. A preceding excitation sometimes produces a degree of activity of the inhibitory focus much greater than that which it would have possessed without the interference of the process of excitation.

In order to make this clear, let us take an example from a very instructive piece of work. Let us suppose that you have some inhibitory, inactive, differentiated stimulus. Let us suppose, in addition, that you have no further need of it and wish to convert it into an ordinary positive stimulus. It might seem that this would be a simple matter, but experiment proves otherwise. It is necessary during this period of the work to beware of employing the usual source of stimulus with which you began your work with the given pair; on each application of it, this ordinary source of stimulus, by producing also induction, but

now of a different character, viz. negative induction, prevents all your legitimate efforts to equalize the effect of the positive and negative stimulating agents (Strogonov's experiments).

It should not be thought that because these experiments with positive and negative induction are performed under artificial conditions they have no practical significance for the life of the animal. As analogous experiments, carried out by the method of conditioned reflexes, have shown, the differentiations connected with applying a succession of positive and negative stimuli to the cutaneous, auditory and visual analysers, are marked by extreme clearness and stability (P. Kupalov). They are also the easiest for our own perception in virtue of the fact that they mutually restrict one another; subjectively speaking, they create unusual clarity of perception.

It is sufficient to remark that all rhythm in music, all composition in the plastic arts and, finally, the monumental "rhythm" of classical colonnades in architecture, is in every case connected with induction, not only in the peripheral auditory and visual receptor organs of human beings, but also in the cortex, which extraordinarily facilitates the process of perception of these highly complex synthetic sources of excitation.

COMPLEX CASES OF INTERACTION OF EXCITATION AND INHIBITION: THE PART PLAYED BY SO-CALLED ACCIDENTAL OBSERVATIONS AND DISCOVERIES IN THE PHYSIOLOGY OF THE CORTEX

In 1913 Pavlov was preparing to deliver a public lecture, together with illustrative experiments, on the

basic phenomena of higher nervous activity, in the large hall of the former Tennishevsky School in Leningrad. A very large audience was expected and, most important of all, the laboratory animals were unaccustomed to an audience and were to "perform" before it for the first time. Nevertheless, Pavlov decided to make no departure from his invariable rule that lectures should always be accompanied by demonstrations. Consequently he had a large number of dogs then undergoing experiment in his laboratories on Aptekarsky Island and on the Vyborg side transferred to the Mokhovaya Street, where the lecture hall was situated.

Certain measures were taken in order to isolate the dogs from the audience. A very large cloth screen was placed between the public and the dog, and by means of a special projector the shadow of the dog was thrown on the screen, together with a much enlarged image of a special horizontal manometer, the red column of which was visible from all parts of the hall, and gave a clear indication of the number of drops of saliva secreted, *i.e.* of the size of the conditioned reflex.

Pavlov's lecture, as always, was of a highly interesting nature, and the audience sat with bated breath. Presently he came to the description of the experiments about to be shown on the formation of conditioned reflexes. We who were assisting him had great fears for the success of the demonstration.

To our astonishment all the experiments succeeded splendidly. On putting into operation each of the previously elaborated stimuli, whether sound, light, heat or contact with the skin of the dog, saliva was secreted accurately, to the general delight of the

audience, many of whom saw this experiment for the first time.

Pavlov's second lecture, which took place some days later, was devoted to a study of the laws of inhibition of conditioned reflexes. The mechanism of this interesting phenomenon has already been described above. Pavlov desired to demonstrate it to his hearers, expecting that in view of the fact that the dogs had already appeared once in the Tenishevsky lecture hall, they would have sufficiently overcome the novelty of their surroundings and would give the same results as were daily obtained from them in the laboratory.

To the great regret of all Pavlov's hearers, *not one of the experiments performed this time was successful*. It would be more accurate to say that the second, important part failed; all the reflexes proved to be present, as in the first lecture, it was only that all *inhibition* was absent. A dog which in the laboratory had been taught to distinguish a tone from a semitone, now, *i.e.* before the audience, reacted positively even to sounds as far apart from one another as two or three whole tones or even more.

But this "failure" immediately gave new inspiration to Pavlov's genius for research. "It is clear," he argued, "that the stimuli of the new environment which were insufficient to inhibit the conditioned reflexes during the first lecture, now entirely abolished the process of inhibition which forms the basis for the differentiation of closely related stimuli."

This conclusion involved another, still more important, that was very soon precisely formulated by Pavlov, *viz.* that the process of active inhibition, if one leaves out of account the individual peculiarities

of the animal, represents a more fragile process than its partner, the process of excitation. The process of inhibition, being more delicate, also develops much later, both in the biological sequence (the lower animals exhibit it to a lesser degree than the higher) and in the course of individual development.

In Pavlov's view, a child exhibits the process of inhibition to a considerably lesser degree than an adult. The child's cerebral cortex, being functionally weaker, is frequently unable to suppress the process of excitation, especially as the latter is reinforced by powerful impulses proceeding from the region of deep-seated specific instincts, the centres of which lie in the subcortical ganglia. This discovery, however, opens up important prospects for the study of so-called *caprices* of childhood and is of great assistance in dealing with the phenomena exhibited by so-called "difficult" children.

Somewhat later, in 1915, another interesting occurrence took place, in which a rather important discovery was made more as a result of a fortunate combination of circumstances than by direct calculation. We say "more," because in point of fact Pavlov does not admit anything accidental in nature; all fortunate and unfortunate combinations of circumstances he uses for more detailed study of the basic laws of higher nervous activity which have so wide an application in everyday life.

During the height of the World War, the permanent staff of Pavlov's colleagues in the laboratory, mainly doctors, left the Institute and were sent to the front, while those few who still did some work in the laboratory spent a large part of their time in the hospitals for the wounded. Pavlov



FIG. 19. Experimental sleep of a dog in laboratory stand (first stage of sleep—eyes open)

was sometimes left in solitude for days together, reading in his study or walking about the laboratory.

On one such occasion his attention was attracted by a dog which one of the experimenters was accustomed to "order" by telephone, that is to say, to avoid loss of time on the necessary preparations for the experiment, he requested the attendant beforehand by telephone to put the dog in the stand and attach the apparatus to its cheek, etc. Having thus "ordered" the dog by telephone, he sometimes forgot about it and only arrived an hour or more afterwards.

On coming into the chamber where these preparations had been carried out, Pavlov noticed that the dog was in a profound sleep, hanging limply in the straps used to hold the dog in the required posture (Fig. 19).

That the absence of stimulation produces drowsiness in the animal had been known already for some time; but that the *conditions of the experiment* could themselves be a source of hypnosis was something which it occurred to Pavlov could be tested in this case with an accuracy previously unattainable. Pavlov had the experimenter perform the following experiment immediately on his arrival: he proposed that after the dog had been placed in the stand a measured interval of time, *e.g.* two minutes, should be deliberately allowed to elapse. At the same time, on the basis of various considerations, he proposed that a test should be made of both components of the usual conditioned reflex, the secretory and the motor effects, *i.e.* the secretion of saliva parallel with the corresponding movement of seizing food.

It was found that in this experiment the dog *did*

not secrete saliva in response to the conditioned stimulus, but that, nevertheless, it seized the food put before it and ate it.

On other days the dog was deliberately made to wait for the experiment for ten minutes. In this case, on applying the conditioned stimulus it was found that saliva was secreted but, in contrast to the preceding case, the animal *did not take food* and even reacted negatively to it. The dog is asleep, but its sleep does not prevent it from seeing and hearing all that goes on around it.

It became clear from this that at a definite *stage* of going to sleep the inhibitory process distributed over the cortex became concentrated as it were in the motor zone. There occurred also a peculiar *fettering* of the movements of the animal and even shuddering, such as everyone has doubtless experienced during the process of going to sleep. This phenomenon of light coherence or catalepsy, as we shall see below, also plays a very important part in the analysis of pathological states of the cortex, of which mention will be made in connection with neuropsychical derangements.

Finally, the test was made of leaving the dog in the stand for half an hour awaiting the experiment. It was found that this resulted in the development of deep physiological sleep, in which both the secretory and motor components of the conditioned reflex disappeared and the whole musculature of the body became relaxed.

Let us recall further a number of remarkable cases which are closely connected with the problems of inhibition and sleep, and assist in explaining the complex mechanism of the latter. The first of these

cases concerned a stray dog that was found in the street, which was operated on as usual and put in the laboratory stand, but was found not to give good results by the method of conditioned salivary reflexes. Unlike other dogs, it moved about restlessly in the stand all the time and continually secreted saliva, as happens with dogs that suffer from hot weather (Parfenov), although it was quite cool in the laboratory. At first those who observed it supposed that the dog simply found it difficult to bear being shut up in the laboratory. But on being released from the stand, the dog at once lay down and went to sleep. After a number of such tests, it was found that this dog had a marked repulsion to any *restriction of its movements*, a special reflex which is not exhibited by many domesticated dogs (speaking from memory, only a few hundred cases were discovered in the laboratory).

We are reminded of wild, undomesticated animals, both mammals and birds. The latter, for instance, on being put in a cage, *i.e.* restricted in their movements, frequently refuse to eat and soon perish, since they are unable to reconcile themselves to being enclosed in a space that is fully sufficient for domesticated birds.

It is interesting to note that the dog mentioned above, on being deprived of food, except for that given him while in the stand, after three months gave conditioned reflexes which afterwards became well marked and stable. Consequently, the food reflex in this dog proved stronger than the other (Gubergritz's experiment).

A third, directly contrary, case occurred in 1921. While at work with a dog by the method of con-

ditioned reflexes we were periodically disturbed by unusual noises proceeding from the adjacent room and by the sound of furniture being overturned. It turned out that this noise proceeded from a small dog with a stomach fistula. This dog stood in the stand in the adjacent room for hours at a time and was very quiet, but as soon as it was removed from the stand it displayed an unusual degree of violence.

When Pavlov learned of the strange behaviour of this animal, he proposed that we should immediately investigate in detail the whole complex of phenomena, and particularly the relation between the period the dog remained in the stand and the strength of the reaction on removing it from the stand, and also that we should investigate its behaviour in the stand as had been done in the two previous cases.

It was found that "Melya" (such was the dog's name) not only stood quietly in the stand like other dogs, but even jumped on to the stand without being told and then remained quietly in a peculiarly tense, as it were "official," pose for many hours, rarely allowing herself a slight movement of the head. The secretion of gastric juice from the fistula proceeded in the normal fashion.

Control experiments outside the stand showed that Melya was a very cautious and even timorous dog; she even ran away from the laboratory rooms where the other dogs were, preferring her "torture" chamber where, apparently, she found the quiet that she longed for, and usually jumped up on to the stand of her own accord. Yet on being removed from the stand she behaved so violently as to upset it—a glaring contradiction in behaviour. The longer she

remained in the stand, the more violent was her reaction on being removed from it; at the moment when the attendant took her by the collar, this peaceable dog was literally transformed into a wild animal; she jumped about so furiously that she upset everything in her path and struck terror into the attendants, as well as greatly disturbing all other workers in the laboratory.

It was clear that we were confronted here once again with a special reflex connected with the individual character of the animal. The process of training here, obviously impinging on a weak nervous system, expressed itself in a remarkable combination of inhibition and excitation. To a certain extent this phenomenon was not new. We frequently had occasion to observe even among so-called "watch-dogs," that even the best individuals of their kind, when deprived of the beneficial influence of natural selection and guarded from birth against any possible injuries, lose one quality that is very necessary for them, viz. courage, which is found developed to a high degree in wild animals of the same species. To put it simply, Melya was a coward. But how to disclose the physiological mechanism of her strange behaviour? We know that there exist cowardly dogs which throw themselves on a human being for no reason at all, as if they were "hiding" their cowardice in this way. The impress of inhibition lies on them for the most part just when excitation is demanded; on the other hand, the latter sometimes accumulates to an extreme degree, making their behaviour violent, and, in the last resort, inappropriate.

This was obviously the case with our dog Melya. As regards the physiological mechanism of this

phenomenon, we are confronted here with the accumulation of inhibition at one point, viz. in the "motor sphere." At the moment when a "change of sign" of nervous activity occurs, this energy passes into another form—extreme excitation. Thanks to our experiments, it became possible to make accurate variations of the extent of this excitation.

This possibility of varying the final effect justified us in terming the phenomenon *self-induction*. Measures were adopted to destroy this self-induction. The dog was removed from the stand, and it was found that when work was carried out with it away from the stand, the dog elaborated successfully a whole series of conditioned reflexes (Abuladze).

The last case concerns one of the lengthy experiments of M. Petrova which was especially useful for analysing the manifestations of individuality in certain dogs. For instance, Petrova worked with a sheep-dog, nicknamed "Usach," which displayed a characteristic guarding reflex, *i.e.* a tendency to "defend" the experimenter from any "attack" on him on the part of those considered outsiders by the dog, which in such cases fell into a state of extreme excitation. This dog did not allow anybody to come into the chamber where the experiments were being made, not even I. P. Pavlov himself, who became extremely interested in this peculiarity of the dog's behaviour and determined to investigate it.

First of all he proposed to test the *strength* of this guarding reflex in the same way as in all the previous cases. For this purpose, in another chamber (the general room) he elaborated a positive reflex to himself on the part of the dog, giving it sausage to eat from his own hands. When this second reflex

was sufficiently strong, Pavlov came into the chamber where Petrova's experiments were being conducted, hiding the food that he had with him. To our general astonishment, even his appearance at the doorway was greeted by the dog with furious barking. The impression was created that the powerful food reflex, universally prevailing among all animals, was vanquished in the struggle with the secondary guarding reflex, which is, moreover, a reflex that has been artificially inculcated in the dog during domestication.

Pavlov, however, here also successfully applied his principle of varying the *strength* of the reflex. He utilized all possible means to "charge" the centre of the food reflex by adding more and more of the conditioned stimulus to it. First, he brought out the bowl with titbits, previously hidden; then, taking one of the titbits in his hands, he found it possible to advance a couple of steps from the door, but any further approach met with marked resistance on the part of the dog, who even attempted to bite him. The two reflexes—the food and guarding reflexes—were at this moment exhibited before the observers like the two pans of a balance in a state of unstable equilibrium. It was only necessary to add a single "grain" to the pan representing the food reflex, and this was done by taking meat from the bowl and giving it to the dog, and at this moment the guarding reaction disappeared: the dog allowed Pavlov to approach its mistress and even to take hold of her hand. From this experiment, which it might seem is frequently encountered in ordinary life (we may recall the numerous means used to lull a watch-dog's vigilance), Pavlov drew the very interesting biological conclusion that "generally the

food centre is much more energetic than the guarding centre. However, for the full manifestation of this strength and consequently for the orderly comparison of the intensities of the reflexes, the competing centres must be equally charged, otherwise the most distorted relations may be observed. With a small charge of the strong centre and a heavy charge of the weak centre, the latter will often preponderate.”¹

This useful rule of charging the unconditioned centre by means of a whole “battery” of gradually intensified conditioned reflexes, this characteristic phenomenon of the “dominants” (A. Ukhtomsky), deserves to be remembered not only by physiologists but by much wider circles of scientists concerned with the analysis of more or less complex features of animal life.

¹ Pavlov, *Lectures on Conditioned Reflexes*, English edition, p. 260.

Chapter V

PAVLOV'S THEORY OF SLEEP AND STATES AKIN TO SLEEP

NORMAL SLEEP AND HYPNOSIS : THEIR ORIGIN AND COURSE

WE shall now give a summary of the main facts that have so far become known about the physiology of sleep. Pavlov's experiments all indicate that the process of internal inhibition in the cortex on the one hand, and the phenomenon that we usually call sleep on the other hand, have very much in common, that these two phenomena constantly pass into one another and replace one another, and that they can be so similar as to be entirely indistinguishable. It should be noted that cortical inhibition can be evoked not only by means of extinction and differentiation, but also by means of various forms of internal inhibition which will be mentioned below.

To secure the disappearance of a reflex and thereby to create the conditions for the onset of sleep, it is not even found necessary to produce extinction; in some dogs it suffices merely to apply one and the same active stimulus several times in succession, without interpolating any other stimulus, and sleep very quickly makes its appearance. Hence every trial of a conditioned reflex, not to speak of tests of differentiation, of itself produces in the brain some degree of exhaustion of the cells and may even

result in sleep. Nothing takes place in the nervous system without cause; everything is entered into the account kept by the cerebral cortex. In essence this is easy to understand; the cerebral cortex exhibiting the highest degree of reactivity requires the most careful treatment.

Some may be inclined to greet this assertion with an incredulous smile. Can it really be true that the superior organ—the cerebral cortex—is so powerless and that it is so weakly armed against sleep?

The fact is, however, that the case taken by us of repeated trials of a reflex is extremely artificial and rarely occurs in practical life. The *normal*, active life of human beings (and of any animals) is never concentrated in any single cell; it usually brings a complex of them into action, excitation passing as a rule from one centre to another, “migrating” by very circuitous routes.

But if in certain cases of the vital functioning of the brain the process becomes concentrated in one particular part of the cortex, then a fall in reactivity gradually but inevitably occurs. Whether this is the result of increased loss of reactivity of the neurones themselves, or whether it is owing to the uncoupling of nervous connections, is a disputed question into which we shall not enter here. The phenomenon of the disconnection of nerve centres, a phenomenon bound up with the need for rest, if it proceeds at the normal time, as part of the rhythm that is biologically determined or individually established, we call *physiological sleep*.

It is clear from what has been said that normal sleep is a *preventative* of exhaustion, a loyal guardian of the delicate cortical activity which, of course, must

not be expended indiscriminately at any time of the day or night; it must be utilized economically for the higher orientation of the animal in its struggle for existence, and particularly in those circumstances which demand the highest degree of "resourcefulness" and the most intense application of all its powers.

This rule receives particularly marked confirmation in working with "unstable" nervous systems, *e.g.* with puppies. In this case it suffices to put into operation a few times in succession some stimulus not connected with eating, but which evokes an investigatory reaction on the part of the puppy, to obtain together with the extinction of this reaction (and as is known this does not require much time) the appearance of deep and tranquil sleep (I. Rosenthal's experiment).

In such a case, before going to sleep the puppies necessarily have to bark a bit and make a fuss, exactly like a human child, with its still unstrengthened system of cortical centres, that sometimes acts capriciously for a long time until sleep at last closes its eyes. Anyone who has observed neurotic children before their bedtime can fully confirm these facts.

One of the cortical regions, viz. the so-called motor analyser, plays a part of the utmost importance in the origin and development of sleep. We have already mentioned one accidental experience, subsequently subjected to thorough analysis, when an animal that had been left 2-10 minutes in the stand under the influence of its surroundings first ceased to give the conditioned salivary reaction (the first phase of sleep) and then lost the capacity for movement, although the salivary reflex was then present. In this second aspect we obtain such a characteristic

situation as when a hungry animal literally falls asleep over its bowl of food and cannot even open its mouth in order to grasp what is before it.

Rojansky, in his experiments in Pavlov's laboratory, went much further; he showed that this state of catalepsy is observed as a transitory phase in all cases of onset of sleep. Hence it becomes possible to understand why restriction of movement of the animal plays so decisive a part in producing sleep.

From Pavlov's standpoint, this second cataleptic phase denotes the cessation of the process of irradiation of inhibition at the boundary of the subcortical centres regulating equilibrium and movement of the body in space (the stato-kinetic centres of Magnus and de Kleijn), the process not yet extending further, *i.e.* actually into these underlying centres.

Recently, in Pavlov's laboratory, we have learned how to prolong this transitional condition between sleep and the waking state to an extreme degree, and have thus been able literally to model the animal like wax into any posture desired.

But if the inhibition, the summation of which takes place in the cortex, increases to a still greater extent, it descends also into the lower "storey" of the brain, where the regulation of movements of the skeletal muscles takes place, and then complete relaxation and full repose of the muscular apparatus ensues. By taking into account the role of the cervical muscles, which are the first to give evidence of exhaustion (the animal's head droops), and by employing a special piece of apparatus attached to the head of the dog, Rojansky studied the gradually increasing depth of inhibition on going to sleep and its gradual weakening during the period of waking up.

In this way it was possible to show for the first time in a very clear and precise form what earlier investigators of sleep had attempted to produce by using, for instance, sounds of varying strength to wake up the subject experimented on. Thanks to the method of conditioned reflexes (in this case motor reflexes) it has now become possible to investigate the depth of sleep without waking the animal, and this is the more important because the process of waking up always gives rise to new, extremely complicated conditions which it is not at all easy to take into account. In the physiological experiment all these conditions are under our control.

Pavlov's laboratory has achieved a most notable success in the analysis of the transition from the sleeping to the waking state. The investigation of sleep made a tremendous step forward when it became possible to unite the method of studying movement with the study of conditioned salivary reflexes, the latter, as we have seen, disappearing in an animal on going to sleep not immediately but gradually and, moreover, in a definite sequence.

I. Rozenkov made an analysis of this question in experiments with dogs, using four conditioned stimuli of various degrees of physiological strength. The first place in regard to the size of the salivary secretion was taken by the sound of a whistle, the second by a metronome, the third by a mechanical skin stimulator—a small pin, and the fourth by the flash of an electric lamp.

By a special method, which consisted in putting two differentiated stimuli, one active and the other inactive, into sharp contrast with one another, he succeeded in producing in the animal experimented

on a state akin to sleep, from which it did not become free immediately, but only over a long period lasting for *several weeks*.

During this period it was possible to observe the successive appearance of three fundamental *phases*, each of which was distinguished by a special relation of the salivary reaction to the stimuli mentioned above (see Fig. 20).

While the phase of full sleep was characterized by the clear absence of any effect on employing all four stimuli, the second phase, the one most closely akin to sleep, was marked by a *paradoxical* relation between the strengths of the stimuli as judged by the salivary response; the stimuli had as it were changed places, the first place being now taken by the flash of the electric lamp, the second by the pin, the third by the metronome, and finally, the fourth by the whistle. We should bear in mind this circumstance of weak stimuli having more effect than strong ones; it has a very important bearing on the phenomena of so-called suggestion observed in hypnosis.

After the lapse of a further period, the dog exhibited a new phase of the sleeping state characterized by the fact that now all the four stimuli proved to be of equal strength, as indisputably evidenced by the equality of the secretory effect. This is the so-called *equalization phase*.

Continuing to trace the re-establishment of normal conditions, the observers made the acquaintance of a so-called *transitional phase*, with its varieties, in which the first place as a stimulus was taken by the second agent, viz. the metronome, followed next by the pin, while the whistle and the lamp gave only a minimal effect. This phase lasted until the animal

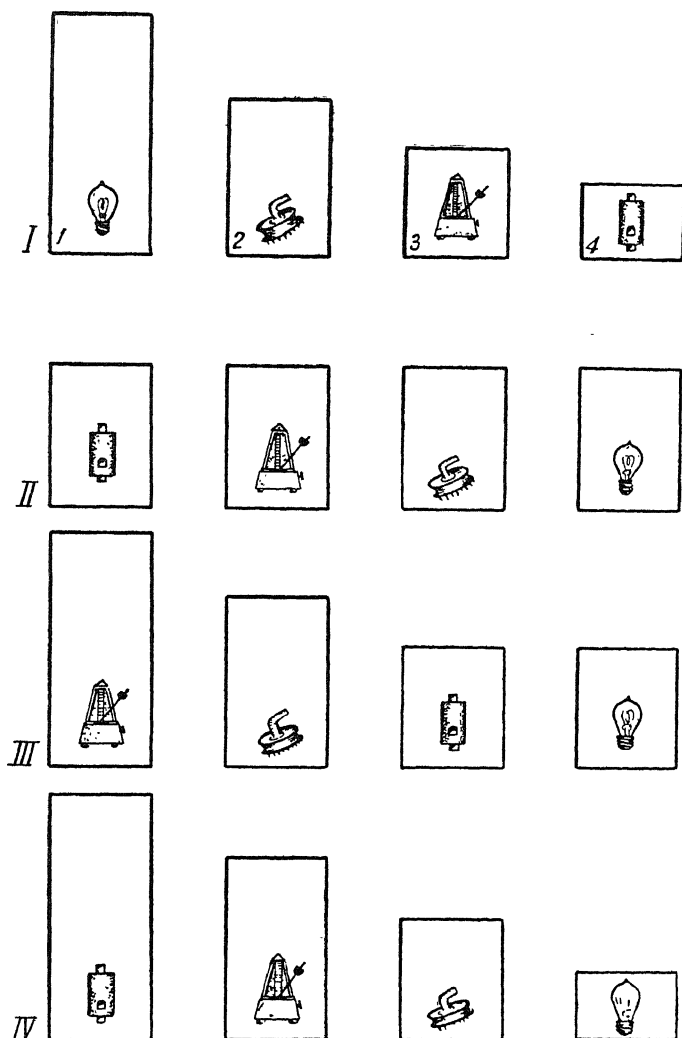


FIG. 20

Diagram characterizing the different phases of sleep in the process of falling asleep.

- | | |
|----------------------------|-------------------------------------|
| 1. Weak exciter—lamp. | I. Paradoxical phase. |
| 2. Pin. | II. Equalization phase. |
| 3. Metronome. | III. Phase of transition to normal. |
| 4. Strong exciter—whistle. | IV. Normal. |

finally threw off its "sleeping" state. When this occurred the relation between the strengths of the conditioned stimuli resumed its normal character.

On appraising the results of this experiment, the question at once arose as to whether these variations in the strength of the reflexes were the result of a pathological state.

Numerous experiments, however, carried out during recent years with exhaustive thoroughness, have shown that all the above-mentioned phases, plus the so-called ultra-paradoxical phase manifested by the appearance of positive effects in response to inhibitory stimuli (*e.g.* in response to differentiation), are characteristic of every completely healthy animal in all cases of transition from the waking state to sleep, and vice versa. The only difference is that in healthy animals these phases are marked by their transitory character and consequently cannot usually be investigated in such detail and fullness as was possible in the case described above, which bordered on pathological sleep. In sick animals these phases could be prolonged for months or even years.

The above-described phases of sleep are of enormous significance both for biology (*e.g.* in regard to hibernation of animals) and for judging the action of the great variety of soporific means now at the disposal of modern pharmacology, that is to say for the study of drugs and their application.

As regards the means for artificially producing sleep, tests were made of the action of certain narcotic substances, as a result of which it was found that, prior to producing complete sleep, these caused a regular and even lowering of all the conditioned reflexes (the so-called narcotic phase).

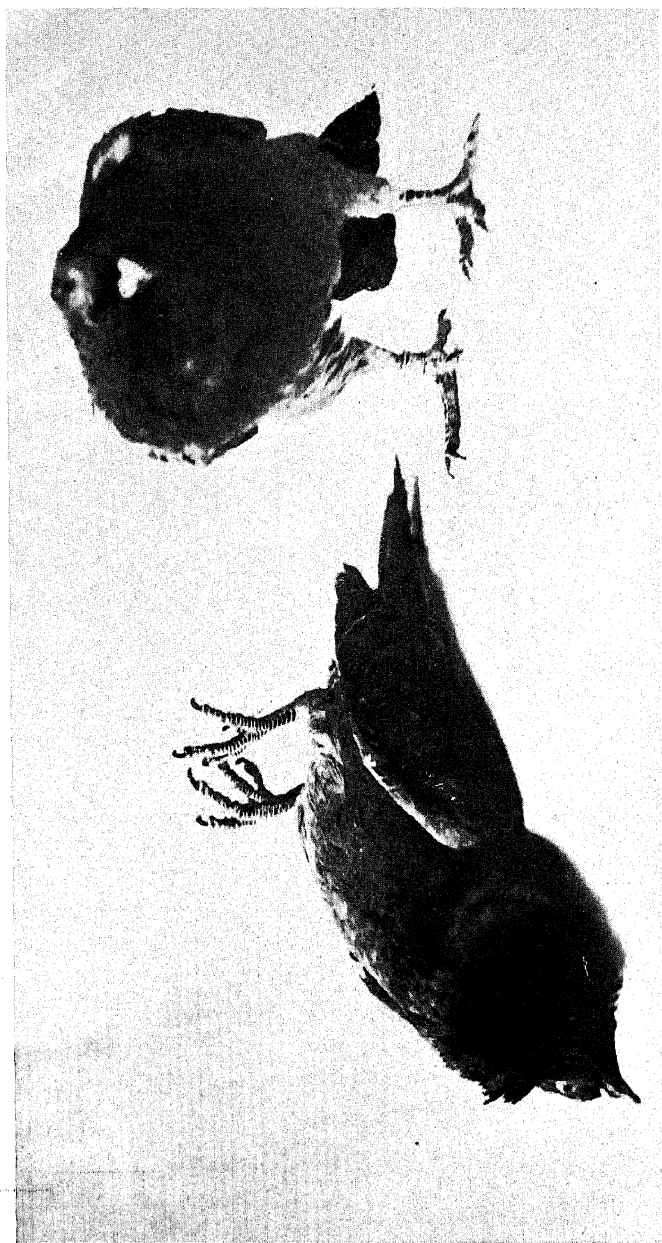


FIG. 21. *Experimentum mirabile* according to Kirchner (a dove in the state of hypnosis—eyes open ; nearby, a dove in normal condition)

Old age in the animal organism was also found capable of causing the periodic appearance and reverse order of all the above-mentioned phases, except the ultra-paradoxical phase, while infancy was frequently responsible for the appearance of the paradoxical phase.

But perhaps the most noteworthy feature of this research was the analysis, from the standpoint above described, of the special state induced in animals, particularly birds, on forcing them to adopt a certain position, *e.g.* by turning them on their back, by pressing the head to the ground, etc.—the so-called *experimentum mirabile* (Kirchner, 1646) (Fig. 21).

This classical means of inducing hypnosis in animals has long been something of a riddle. Now we are able to speak of it as of any other physiological phenomenon depending on the special state of the cerebral cortex of the animal, in other words as a special kind of reflex representing an important supplement to the previously mentioned reflexes of Magnus and de Kleijn.

In point of fact, while the restriction of many elementary movements characteristic of the animal can give rise to inhibition in the cortex, on the other hand by producing inhibition through one means or another we may achieve a considerable restriction of movement, so to say a catalepsy of the first degree, in which the body of the animal will be immobile while the eye or head will retain its capacity for movement. Further, we may obtain catalepsy of the second degree, manifested by complete immobility of the animal, including the head and eyes. With a still greater increase of inhibition we can obtain complete relaxation of the musculature of the body, and con-

sequently deep sleep as described before. In my latest experiments with domestic and wild birds I have made a special study of this question, and it has been found that the capacity of becoming immobile under the influence of compulsory restriction of movement is characteristic of all species and ages. It is interesting to note that the *experimentum mirabile* is characteristic not only of birds but also of rabbits, dogs and even fishes (the so-called *Todstill reflex* of German authors).

THE CEREBRAL CORTEX AS A DYNAMIC SYSTEM

So far we have dealt with the methods of producing the sleeping state in the animal and with the distinction between the separate phases in the development of sleep.

We propose now to say a few words on how to *preserve* the waking state of the animal, on how to prevent the intervention of sleep in the normal course of experiment.

It must be remarked that as time went on this problem of the real conditions of life in the laboratory took on a very acute character. Owing to ignorance of the conditions for maintaining the normal working capacity of our animals at the requisite level, we frequently observed that the majority of the dogs became less capable of working precisely on account of drowsiness.

Hence it was natural to look for means for dispelling sleep or to choose individuals distinguished by their vivacious character, *i.e.* externally lively and active dogs. This, however, did not lead to the desired results. A solution of the problem was

then sought in the use of strong stimuli, but here again we were cruelly disappointed. None of these measures had the slightest effect in preventing the development of sleep in certain dogs; they sometimes even enhanced the tendency to sleep.

The first success in the struggle against sleep was secured by using a means that amounted to employing *short periods* of action of the stimulus. On shortening the period of the *isolated* action of the conditioned stimulus, animals that were already on the point of going to sleep became more lively and worked well (Petrova). The most effective means, however, in the struggle against sleep was found to consist in introducing into the experiment well-elaborated *differentiations*, *i.e.* achieving in the brain a precise, clear delimitation between active and non-active stimuli. Let us suppose that we have a reflex to 104 ticks of a metronome per minute. The dog will sometimes secrete saliva in response to it and sometimes will not do so; moreover, at times it will doze or even go to sleep. Let us now begin to elaborate an inhibition (a differentiation), say to 180 ticks per minute of the same metronome. It suffices to strengthen this differentiation to a sufficient degree and a double benefit is obtained; the reflex to the metronome with 104 ticks becomes more constant in magnitude and at the same time sleep disappears. Thus, internal inhibition produced by differentiation assists in abolishing sleep.

This is wholly satisfactory, but then the question arises: how to reconcile this state of affairs with Pavlov's basic proposition mentioned above, *viz.* his assertion that sleep and internal inhibition are one and the same process? Is it not the case that all

inhibition ought to strengthen sleep, while in this last experiment it does away with sleep altogether?

Those who question in this manner usually forget that so far we have been speaking of the general characteristics of sleep. From the standpoint of their physiological nature, internal inhibition and sleep undoubtedly represent one and the same process. But it must not be forgotten that all processes in the brain are restricted in time and space and that they can enter into the experiment only in their space-time character. From this latter point of view, an inhibition can be either *spread over the whole cortex* and, moreover, possess a lingering character, or it can be strictly *localized* at some one point of the brain. In the first case (irradiation of inhibition) you have sleep, in the second case (concentration of inhibition) you have, on the contrary, the optimal waking state of the cerebral hemispheres.

The most intense waking state is connected with the most concentrated form of inhibition. It is impossible not to agree with this if one remembers that a person who is wrapped up in one idea, as for instance happens with many scientific workers who devote themselves to realizing some cherished project, literally sees and hears nothing of what goes on around him. And what a misfortune if such a person has to deliver a report at some specially busy session where the agenda is strictly limited in time! In such a case the enthusiastic speaker will unfailingly find himself reminded by the chairman that his "time is up."

From Pavlov's point of view, therefore, the cortex of a lively, active brain, in particular if this brain is occupied with complex, responsible work, represents a very complex, changing *mosaic* con-

sisting of groups of neurones with different degrees of excitation or inhibition. In proportion as they are affected, with every alteration of states and experiences, these points and foci change places; a point where there was previously excitation now becomes the seat of inhibition, and vice versa.

Consequently, Pavlov's "mosaic" is not something petrified or static; on the contrary it is very changeable, very mobile, like everything that is connected with the functioning of this most reactive apparatus—the cerebral cortex.

If the skull were transparent, says Pavlov, and the active centres had the property of emitting light, then external observation would give us a picture of an illuminated patch of very complex form which gradually moved about, continually encroaching on some portions of the cortex and deserting others. This illuminated patch would correspond to the region of maximum excitation, the "creative" portion of the hemispheres at the given moment.

If we reflect on this comparison of Pavlov's, it will be realized that this was essentially bound to be the case. Every intense activity of the brain demands a corresponding period of rest for the restoration of the reserves that have been used up. The more intense the strain, the more prolonged is the recuperation required. In contradistinction to all other organs, the cerebral cortex, this most highly perfected organ, rests *during the period of work itself*, providing us with a remarkable example of the capacity for substitution during functioning such as can hardly be found in observing the work of other organs of the body or other parts of the brain.

There are, however, exceptions to this rule also;

there are cases when the mosaic is replaced by sharp "illumination" of only a single point in contrast to all the others which are given the possibility of being immersed in deep sleep. Of course, all these cases where a single point of the cortex is "illuminated" must in some measure correspond to fundamental requirements on the part of the organism, and must be supported by the activity of unconditioned centres situated below the cortex.

This phenomenon, which Pavlov termed the phenomenon of the "watchman," was known as long ago as the period of Francis Bacon. The latter

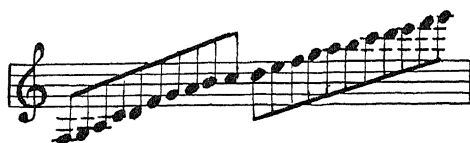


FIG. 22

The gamut of tones. One of them is made active, the rest inactive.

emphasized that a miller sleeping amid the noise of his mill and the creaking of the water-wheel, will inevitably wake up soon as there is any interruption in the work of the mill, particularly if it comes to a stop. Again, a mother with her child will sleep calmly even in very noisy surroundings, but she will wake up at once if the child changes the rhythm of its breathing or makes a movement in its cradle.

A vivid example of the interesting phenomenon of the "watchman" is provided by Birman's work on dogs, in which twenty tones of a harmonium were made inhibitory by means of systematic extinction of the response to them. Only a *single tone* occurring approximately in the middle of the scale (see Fig. 22)

was made an active stimulus, *i.e.* connected with eating. It was very interesting to observe how the dog, apparently immersed in deep sleep during the experiment, whatever the varieties of this "music" that were played, woke up when the "eating" tone sounded. As soon as this single tone was struck, the dog immediately began to stir, to lick its lips and secrete saliva in the usual quantity.

POSITIVE AND NEGATIVE REFLEXES AND THEIR TRACES
IN THE CEREBRAL CORTEX: PAVLOV'S ATTITUDE
TO FREUD'S THEORY

Although the modern theory of dreams is based almost exclusively on self-observation and questioning, it is not without interest to contrast this mass of subjective material with certain facts obtained by the method of conditioned reflexes in animals. Some observers of animal life have looked for an answer to the problem of dreams in the movements which, for instance, a dog carries out in its sleep, such as moving its paws in a definite rhythm as if running or as if occupied in catching a non-existent fly.

We approached the problem of dreams not from the motor aspect but from the secretory aspect, *i.e.* that of conditioned salivary reflexes. For this purpose it is necessary for us to introduce one more conception to supplement those new conceptions with which Pavlov's theory is so richly endowed. Here it is a question of the so-called negative conditioned reflexes and their traces remaining in the cerebral cortex after the stimulus has disappeared.

As a basis let us undertake the analysis of an ex-

periment carried out by G. V. Volborth as far back as 1910. For this experiment a natural conditioned reflex was selected, *e.g.* the reflex to the sight and smell of meat powder, and the experimenter began to extinguish this reflex by the means already described above, that is by not giving the dog food. When the state of inhibition thereby produced was sufficiently developed, he introduced into the experiment a conditioned stimulus, one hitherto absolutely indifferent to the animal. By systematically repeating this experiment, the result was achieved that it sufficed to present this new stimulus to the dog and the latter became perceptibly inhibited, although except for this special function it continued to work, remaining in a fully waking state.

This was a very remarkable experiment; we were aware that an indifferent stimulus impinging under ordinary circumstances on an active state of the cortex (in consequence of the close proximity of the food excitation, *i.e.* the act of eating), acquired by means of the establishment of the temporary connection the character of an exciting agent. We now know that the same, *i.e.* an indifferent, exciting agent, impinging on an inhibited state of the cortex acquires the character of an inhibitor, in particular it becomes capable of causing sleep.

It was legitimate to term this second phenomenon a negative conditioned reflex—a term which has subsequently been regularly employed in the literature to cover an extensive group of phenomena of this character.

It has become clear that the life of an animal and its interactions with the surrounding environment are by no means confined to the formation of positive

conditioned reflexes alone. It is necessary to recognize now that they are supplemented by special *minus-reflexes* which are actually encountered no less frequently than the *plus-reflexes*, which have been so far the subject of our exposition.

It was very soon shown by experiment that these new reflexes could be elaborated fairly easily with other forms of experiment also, and that the laws of their formation could be established with particular accuracy if one adopted the following form of experiment, which for the sake of brevity can be represented by means of a short formula.

Let us suppose we have:

$$\begin{aligned} a &= A \\ a + a &= 0 \end{aligned}$$

where "*a*" is the conditioned stimulus, *A* is the unconditioned stimulus (eating) and *a* is the additional stimulus which we introduce into our experiment and which gives the combination *a*+*a* that is never reinforced by eating, *i.e.* that gives an effect equal to zero.

When, after fairly numerous trials, these two experiments were realized in sufficient purity (which is easily obtainable in the case of the dog), then by testing other active stimuli, *b*, *c*, *d*, taken from the same or from other analysers as "*a*," we get the following result:

$$\begin{aligned} a + b &= 0 \\ a + c &= 0 \\ a + d &= 0 \end{aligned}$$

in spite of the fact that the stimuli *b*, *c*, and *d* taken by themselves are excellent exciting agents of the conditioned salivary reflex,

From this only one conclusion is possible: that α is a "supplement" which inhibits all other stimuli that are connected with it. And since this inhibitor has been formed deliberately, it was decided to call it a *conditioned inhibitor* or *negative conditioned reflex stimulus*.

A negative conditioned reflex is in many respects similar to an ordinary positive reflex, but this resemblance may be reduced to practically nothing.

The negative reflex, as we have seen, can not only be elaborated by methods very similar to those described in the previous chapter of this book dealing with positive conditioned reflexes, but it can also be extinguished by approximately the same methods as were described at the beginning of the present chapter.

In spite of all external resemblance, however, the essence of the matter is that all the above-mentioned laws will be exhibited here in reverse form. For extinguishing a conditioned reflex it is necessary not to reinforce it by eating; on the other hand, for "extinguishing" the newly arisen negative conditioned reflex " α " it is necessary to reinforce the combination $\alpha + a$ several times by giving food, *i.e.* to make $\alpha + a = A$. The same thing must be undertaken to get the animal to differentiate clearly two negative reflexes from one another; for this it is always necessary to reinforce $\beta + a = A$, leaving unchanged the combination $\alpha + a$ without reinforcement (Nikolayev).

These new combinations that make their appearance during the work under the influence of the negative stimuli " α " must not cause us to think that α is a sort of parasite that settles on the "body"

of the conditioned reflex. Nothing of the kind; the complication mentioned is only the result of the fact that a negative conditioned reflex can only be expressed physiologically by the abolition of an effect (in this case abolition of the secretion of saliva) resulting from the action of a positive conditioned stimulus.

With the introduction of the new conception—the negative reflex—the theory of the functions of the brain was enriched to no less an extent than algebra had been enriched by introducing the conception of negative and imaginary magnitudes. We now know that the characteristic “scale” of the higher nervous processes observed in the cerebral cortex stretches not only “above” but “below”; we know that the higher nervous activity even of our experimental animal, the dog, is at least twice as rich and complex as it appeared to be previously.

Since negative conditioned reflexes are a superstructure built on positive reflexes and correcting them, it may be said that by obtaining control over the negative reflexes we learn to guide precisely that process in the brain that determines the higher orientation of the animal. Is it not the case that under the actual conditions of the struggle for existence some very small correction to a stimulus may sometimes decide the success of the whole work of the brain? It is interesting to note that the American behaviourists, while continually calling attention in their works to the possibility of forming conditioned inhibitors, themselves make very little use of them; in fact it would be more correct to say that they do not use them at all. Thus they leave in darkness a good half of animal behaviour, the

half that they are not able to explain by "simple" conditioned reflexes.

The question further naturally arises: If positive and negative reflexes so closely resemble one another, should it not be possible also to observe the formation of negative trace conditioned reflexes or inhibitions?

It is found that it is quite possible to achieve this, with one reservation; for so doing it is essential that there should exist a definite relation between the strength of the conditioned stimulus and the size of the pause. With an arbitrarily selected strength of the conditioned stimulus "*a*," the trace of which we desire to utilize in our experiment, it is found that the effect obtained depends on whether we choose an interval of fifteen seconds or one of thirty seconds. In the first case we obtain from the stimulus "*a*" a negative conditioned reflex or conditioned inhibition (experiments of the author), while in the second case we not only do not obtain an inhibitory effect but even get a so-called conditioned reflex of the *second order* (experiments of Fursikov).

This somewhat unexpected result of the appearance of a reflex of the second order depends on the fact that the procedure of elaborating a conditioned reflex of the second order is essentially the same as the procedure of elaborating a conditioned inhibition; the procedure comprises the coupling of two stimuli "*a*" and "*a*" without reinforcing them by the unconditioned reflex, *i.e.* by eating. It may be noted that if we were to reinforce our combination by eating, then we would obtain a simple conditioned reflex (of the first order) to the sum of the stimuli, and the whole activity of the nervous system would

come to an end at this first stage. Consequently, in this particular case, *i.e.* when we are dealing with traces of a conditioned inhibition, the result of the experiment depends entirely on the strength of the stimulus and on the period of time that elapses.

If such is the case, then traces of inhibitory stimuli, of which there are certainly very many in every functioning brain, are—under the influence of time and when taken under special conditions with a definite state of the cortex as, for instance, during sleep—capable of acquiring unexpected activity, of reviving, of attaining great clearness, just as we saw in another experiment where it was a matter of undulatory extinction. In our opinion the secret of the physiological riddle of normally occurring dreams lies in these phenomena of the conversion of trace inhibitions into conditioned reflexes and also in the capacity of inhibitions to be extinguished in an undulatory manner like conditioned reflexes, giving a regular alternation of activity and passivity.

In Rojansky's experiments, we saw that the depth of inhibition in the separate phases of sleep was far from being constant; in particular, during the hours of going to sleep and waking up it was lower than during the middle portion of the sleep period. Consequently it becomes comprehensible that dreams most frequently arise during the period when sleep is not profound, when the remains (traces) of previously existing excitatory and inhibitory stimuli combine to make up fantastic patterns. These traces are governed by the same laws of the formation of reflexes, of irradiation, concentration and induction, as are the traces in a waking brain. However, the difference consists in the fact that these combinations

have no real basis, which, as we know from Pavlov's theory, can consist only in the close relation of the conditioned reflexes to the unconditioned needs of the animal. In the sleeping state, however, inasmuch as this unconditioned basis is lacking or extremely inhibited, all the combinations of traces come to have an incoherent, as it were deliberately confused, character.

We are not speaking here of so-called nightmares, which are the traces of recent stimulations, mainly from the immediately preceding hours and days, and are only slightly distorted by sleep inhibition. Such dreams, of course, do not allow the cerebral cortex to recuperate and cannot be called normal.

The subject matter of the majority of dreams, however, consists of old recollections of impressions received in a long-past period, predominantly of a visual character; sometimes pictures appear in sleep representing experiences in early childhood which we have long ago forgotten. All this only once again proves that dreams represent precisely a manifestation of these characteristic inhibitory traces. Their revival and conversion into active "images" takes place only after the lapse of time, this basic condition for our existence.

Hence there is no doubt that the laws of dreams are sufficiently "firm," but they are not special laws; for the most part they represent only a distortion of the laws of the formation and disappearance of ordinary conditioned reflexes.

In dealing with the subject of dreams it is necessary to point out Pavlov's attitude to the theory of the Viennese psychiatrist Freud, that talented investigator and interpreter of dreams. We have in

mind here only the first period of the activity of this scientist, viz. the time when he was interested in dreams on the plane of "the psychopathology of everyday life."

The later productions of Freud, "the Ego and the Id," etc., in which he began to work out his new theory of the unconscious in the spirit of Hartmann, encountered the most energetic resistance and rejection on the part of Pavlov. This was only to be expected, since Pavlov and Freud were, as regards their interests, and their views on life and on the tasks of the science of behaviour, two opposites who could hardly be combined. While Freud made use of intuition and mythology, and with the progress of time buried himself ever more deeply in the mysteries of the "unconscious," even declining to employ modern objective methods of research, Pavlov in accordance with his unvarying character as a scientist concerned himself for the universal spread of the bright light of knowledge even where it was a question of the depths of pathological personality. And it is not to be wondered at that in so doing he sometimes had to shatter a mass of accumulated superstitions and prejudices, the development of which Freud's successors have done not a little to foster.

We speak here of the early views of Freud, who observed and attempted to comprehend many extremely interesting characteristics and laws of human behaviour. Notably, he collected a wealth of data for the study of so-called involuntary mistakes: forgetting of proper names, slips of the tongue and of the pen, etc. Pavlov was very fond of putting forward Freud's first and clearest example, the forgetting of proper names even of close acquaintances, as a

proof of the law of negative induction analysed by us above. It is well known that the more we try to remember a name that we have forgotten, *i.e.* the stronger the process of excitation that we evoke in the brain, the more difficult does it become to recall the desired combination of sounds.

Pavlov raised no objection either to Freud's conception of the forgetting of painful impressions, which nature endeavours to eliminate as it were by developing an inhibitory state in the parts of the brain concerned, sometimes of a very intense character (Freud's example of the forgetting of the name of a patient who had died). Freud, however, goes much further; from his point of view human personality is the scene of a collision between, on the one hand, obscure instincts, our unconscious desires that are chiefly of a sexual character, and on the other hand the inclination of our consciousness, of our "Ego," the latter being the result of education and the development of man in society.

According to Freud, our "Ego" up to a certain time always holds our desires in curb. Thanks to the control of consciousness, certain unrealized desires are as it were thrust below the threshold of consciousness, and from their place in the unconscious continue to act on our minds. Hence arises the *sublimation* of these desires in the form of pre-occupation with art, science, etc. Sometimes, however, these aims, having their origin in the sex centre, as it were evade the control of consciousness and make their appearance either in dreams, when consciousness is lulled, or manifest themselves in waking life in various mistakes, slips of the tongue and all kinds of accidental effects as, for instance, the

above-mentioned acts of forgetfulness. According to Freud, the meaning of these mistakes is concealed from the conscious mind, but their content has always some definite connection with the repressed desires that give rise to them and represent as it were a substitute for the desire.

If we are to believe Freud, the whole mechanism of the origin of these mistakes functions without the participation of our consciousness, for a sick person who is compelled during the process of analysing his personality to recognize the existence of these powerful and often strange desires in his psyche, even resists and refuses to recognize the truth of the findings of the physician, although the latter has fully "unmasked" him.

There is nothing to object to in the view that dreams may in some measure present a picture of unfulfilled wishes, perhaps even unknown to the subject himself, *i.e.* existing below the threshold of consciousness or, in Pavlov's terminology, inhibited and occurring outside the limits of the "illuminated" portion of the brain.

But this recognition of the importance of the characteristic sleep activity carried out on the traces of real stimuli, chiefly visual stimuli, by no means signifies that the "complexes" thrust into the unconscious sphere must necessarily belong to sexual reflexes or ideas, as Freud imagines.

Here Pavlov energetically opposed Freud's views, pointing out that any complex of stimuli under appropriate conditions can become inhibitory, and as such essentially influence the activity of the brain while itself remaining in the background or outside the main path of the usual working of the brain.

We shall conclude this chapter by a short account of an experiment with negative conditioned reflexes which we were commissioned to perform by Pavlov, and which contributes its share to throwing light on the Freudian doctrine of the "unconscious."¹ The experiment was made with dogs and with the same trace stimuli dealt with above.

The reader will remember that we had a very highly trained dog, "Prima," in which we had elaborated a conditioned reflex to the ticking of a metronome. Continuing this work, we joined to this reflex the sound of a trumpet, appearing a little prior to the metronome, and this combination was never reinforced by eating, that is we elaborated from it a conditioned inhibition to the metronome. Thanks to the considerable period over which the experiment was carried out (two years), by gradually separating the sound of the trumpet from that of the metronome we finally reached a position when the trace of the trumpet after sixty seconds was capable of exerting an inhibitory action on the conditioned reflex to the metronome.

It should be added that this trace inhibition was differentiated by us from its neighbours—the sounds of other trumpets differing in pitch and timbre. In this way we still further heightened the precision of localization of the inhibitory focus.

We had, therefore, in the auditory analyser of the dog a very firmly consolidated "complex" of nervous processes, a sort of coagulated "clot" of inhibition. Up to a certain time, however, the presence of this complex was not felt either by the dog or by us, since

¹ See Pavlov, *Lectures on the Work of the Cerebral Hemispheres* (Russian).

the experiments proceeded excellently and the dog never went to sleep on testing the inhibitor, which, as remarked, was excellently differentiated and therefore restricted within very narrow limits in the brain.

When we had completed this first task and had obtained complete success in working with the trace inhibitors, we decided to pass to the elaboration of a completely ordinary conditioned reflex to a sound produced in a telephone receiver. Under normal circumstances such connections had been elaborated in dozens, especially in dogs like Prima. This time, however, we were deceived in our calculations. To our astonishment, the dog Prima was incapable of dealing with the very simple and easy task which we put before it. Then, to determine the part played by the telephone receiver in this experiment, we caused it to sound before the metronome, *i.e.* we made it act like a conditioned inhibitor. It was found that the metronome was actually inhibited by the sound of the receiver. It became clear that the resemblance of these two sounds, that of the trumpet and that produced in the receiver, both being prolonged uninterrupted sounds, was an inhibiting agent. Furthermore, we discovered that on testing the receiver and even in response to the ticking of the metronome our dog began to go to sleep, a thing that had never previously taken place.

Consequently, the complex already began to reveal itself in an unfavourable effect on the basic aspects of the dog's behaviour ; it began to affect her hitherto impeccable working capacity.

This state of affairs persisted, for we had no means of breaking up this complex from the outside. The

dog continued to exhibit inhibition and even began to refuse food.

At this time a psychiatrist was working in the laboratory who, like many others just then, was attracted by psychoanalysis. He once told us of a strange case of one of his patients, a woman already middle-aged and by no means given to jokes, who appeared at the clinic with her own chair and who refused to seat herself on any other article of furniture, however comfortable.

In private cross-examination it turned out that the patient when very young had married a man who did not love her (he was in love with another woman) but who had married her for the sake of her money.

Very soon her parents-in-law began to find fault with her appearance, which was not particularly attractive, and made use of the expression that she "had no place in their house."

From this time the patient, who was of a weak character and inclined to depression, began to avoid using their furniture, and ended by carrying about with her everywhere a portable chair, avoiding contact with any furniture, although many years had passed since the day of the insult and she had long since lost both her original mood and her husband.

This case of the insulted widow, perhaps very commonplace from the clinical point of view, helped us to solve successfully the problem raised by the experiments with the dog Prima.

We argued as follows: the inhibition in our dog from the continuous sound was no less ancient than the inhibition which occurred in the parallel clinical case. Consequently, in Freud's language, it would

“resist” all our attempts to combine any kind of sound with the act of eating.

Nevertheless, we took the view that our position was more favourable than that of a clinician, who in such cases has to have recourse to a complicated psychoanalysis, *i.e.* who can use only the recollections of the patient. In our experiment we knew all the conditions which had given rise to the inhibition. Consequently we had only to go back to the starting-point, *i.e.* the day when our experiments began (two years previously), to the circumstances in which we elaborated the inhibitory focus concerned, and attempt to break down this focus from within, *i.e.* to do what is done by the psychiatrist when, having arrived at the “root” of the disease, he attempts by persuasion to free the patient from sufferings of which he or she is frequently unconscious.

Our line of argument seemed to us quite valid. We immediately went back to the combination of the sound of the trumpet with the metronome and began systematically to reinforce this combination by eating.

This time it was not necessary to continue the “sittings” for a long time. As early as the second or third day the dog began to yield saliva in response to this combination of stimuli. At the same time its drowsiness also vanished and never afterwards returned. The dog could be considered cured.

Here the method of psychoanalysis, which in this experiment appeared open to question, was itself successfully subjected to *analysis* from the physiological point of view.

In the case described the whole process of the illness from the moment of its origin was in our

hands, hence the prompt cure effected. An entirely different result was obtained in another case with another dog, in which we had elaborated a positive trace reflex to the sound of a Galton whistle, reinforced by the unconditioned stimulus of inserting a dilute solution of hydrochloric acid into the mouth. The insertion of the acid did not take place immediately, as is usually done when elaborating a conditioned reflex, but after an interval of thirty seconds from the time when the whistle had stopped sounding. Thus it was not the action of the conditioned stimulus itself that was reinforced by the unconditioned reflex but its trace or, more exactly speaking, a definite degree of the process of extinction in the corresponding cells of the cortex.

As in the above-described experiments with the dog Prima, here also we made it our aim to facilitate the dog's complicated brain activity, that is to say we attempted to transform the reflex from a trace reflex into an ordinary one. For this purpose we began to insert acid into the mouth during the period of action of the whistle, *i.e.* altogether abolishing the pause. However, contrary to all our expectations, the dog did not at all reconcile itself to the new state of affairs and continued to give a reflex of a trace nature, *i.e.* it secreted saliva only after thirty seconds although acid had then already been in the mouth for some time. Owing to the absence of saliva, the appearance of which was retarded, the acid began to exert a deleterious action on the mucous membrane of the mouth, which was deprived of its normal protection, the secretion of saliva.

It followed from this experiment, as from the first part of Yerofeyeva's experiment with the electric

current, that a well-inculcated conditioned reflex may prove to be stronger than an unconditioned reflex, *i.e.* an innate and apparently more powerful defensive instinct. This phenomenon served once again as a sort of bridge to the study of the pathological distortion of the brain's activity, since there was an evident lack of correspondence between the reaction of our animal on the one hand and the actual state of affairs on the other. In this case the unpleasant reality was represented by the acid.

In spite of the fact that we could so well understand the roots of the dog's pathological state, we were unable to remove it. The dog became more feeble and drowsy every day, it began to lose weight, and finally perished with the development of so-called neurotrophic disturbances. These disturbances, as is well known, depend in their turn on a derangement of those parts of the nervous system which are immediately concerned with the nourishment of the organs and tissues and are closely connected with the activity of the higher cortical centres, which in this case were impaired beyond recovery.

With this we shall conclude our remarks on the inhibition of conditioned reflexes and sleep, considered from the physiological standpoint. We have arrived at a new turning-point in our route. Like travellers investigating unknown mountain paths we have proceeded with the utmost caution and concentrated our whole attention on each step taken. The separate facts constitute the steps which we have cut in the ice and which have served to support us in our endeavours to reach the heights of the science of the brain. We can now cast a glance back at the path

traversed. Now that we have made clear the importance of the laws of inhibition, it cannot be disputed that our horizon has become much wider than it was before, when we were only concerned with conditioned reflexes as active forms of the interaction between the organism and its environment.

Nevertheless, we have still not yet attained the final point of our journey, the mountain peak from which there would open before us a view of the flowering valleys. Even now, after the brilliant discoveries of Pavlov related in this chapter, there still remains much that demands the close attention of succeeding generations of scientists.

"This new department of physiology," says Pavlov at the conclusion of one of his *Lectures*, "is indeed a fascinating one, satisfying as it does two inseparable tendencies of the human mind; the constant endeavour to lay hold of new truths and the continual protest against any claims of finality in the attainment of knowledge. Here the mountain of the unknown will long remain immeasurably greater than the fragments that we can break off, that we can learn to know."¹

Judging from a purely physiological standpoint, all normal and pathological cases of behaviour are a question of mutual relations of separate parts of the nervous system, of the activity of those interesting structures situated below the cortex to which Pavlov gave the general designation of "proximal sub-cortex." Of course this does not mean that we should sharply contrast with one another the cortical and subcortical structures, for the latter also contain

¹ Pavlov, *Lectures on the Work of the Cerebral Hemispheres* (Russian).

grey matter, *i.e.* they have approximately the same structure as the former. Moreover, histology shows that all these cellular aggregates are united among themselves by a network of nerve fibres connecting both "lower" and "higher" in a single vast complex which it is often difficult to separate into its component parts.

Physiologically, the most important circumstance for us is that these "subcortical" centres, or basal ganglia, are immediate regulators of very important bodily, *i.e.* vegetative, functions. Thus, for instance, the corpus striatum is connected not only with the motor organs, as is excellently demonstrated by the derangements found in lesions of this part of the nervous system, but also, together with the hypothalamic centres, with vaso-motor functions, with heat regulation and sugar metabolism, and finally with the stomach, intestines and bladder. Hence they are connected with just those functions that are usually considered as not being controlled by the will. It may be remarked that all the functions enumerated, apparently so deeply hidden in the organism, at the same time enter into the composition of almost every instinctive act, of every emotional expression, in short, of every complex unconditioned reflex. It is precisely these functions that are responsible for the complexity of higher nervous activity. It is no wonder that these centres may enter into temporary connection with various phenomena of the outside world. Consequently, to a certain extent these parts of the brain also may be the object of action of conditioned reflexes. Finally the anterior portion of the infundibulum is the seat of an important collection of functions, chiefly re-

lating to internal secretion, *i.e.* to the basic chemical regulation of the organism.

It is clear that this area as it were represents the interests of almost the entire animal organism; the nerve fibres directed hither from the hemispheres are not to be looked on as mere nerve connections, but as embodying the possibility that the higher cerebral centres may influence the general activity of the organism in its highly complex mutual relations with the chemical and physiological factors of the surrounding environment.

Chapter VI

EXPERIMENTS WITH ANTHROPOID APES AND THE COMPARATIVE PHYSIOLOGY OF CONDITIONED REFLEXES

PSYCHOLOGY AND PHYSIOLOGY IN THE STUDY OF BEHAVIOUR OF ANTHROPOID APES

CERTAIN of the experiments which Pavlov carried out in the last period of his life have a very close bearing on a question of prime importance, viz. that of the origin of instruments of labour. We have in mind the experiments performed at the Koltushy Biological Station with two anthropoid apes, Rafael and Rose.

The outstanding problem of the origin of the characteristic brain relations connected with elementary forms of the use of tools has been repeatedly raised also by opponents of Pavlov's views, the advocates of idealist psychology. Previously, the idea of the possibility of purely psychical reactions in animals was reached by reasoning only, without recourse to experiment. Now, with the development of laboratory technique, idealist psychologists, including among them W. Köhler, have established a special research station for studying the behaviour of anthropoid apes, in particular for studying their *intelligence*.

Starting out from the preconceived notion that Pavlov's theory of conditioned reflexes as applied

to the study of behaviour, like the works of some American behaviourists, disintegrates the entire activity of living matter into unnecessarily minute elements, Köhler and his followers began to look for some synthetic form of activity which would be characteristic only of the higher representatives of the animal world, a form of activity which would be displayed from the outset in a fully-developed condition without previous elaboration and which, finally, would not be connected with any visible external activity, in short, a form which would exactly recall the birth of innate ideas.

Hence it is not remarkable that these idealist psychologists, becoming experimenters for the time being, found what they wanted by experiments with apes, for what they wanted was what they were already acquainted with by means of self-observation. They found that when an anthropoid ape is faced with the necessity of obtaining some attractive fruit which has been hung just out of reach, it only *at the beginning* uses the method of trial and error, *i.e.* follows the behaviour expected by the behaviourists. Immediately afterwards, as if convinced of the futility of its efforts, the monkey suddenly becomes quiet, even sits down at some distance from its goal, and then suddenly jumps up, grasps a stick lying in the vicinity, or climbs up on to a box of suitable dimensions, and reaches the fruit. Köhler has given the internal cause of this phenomenon the special name "*Gestalt*" (form, shape). The monkey is supposed to be capable of creating "images" of objects and actions. Although it may not be a frequent occurrence, nevertheless ideas may arise in its mind. Köhler supposes that these ideas can be con-

nected with the use of the stick or box as primitive tools.

In its most general form Köhler formulated the principle of investigation used by him as follows: The experiment gives rise to a situation in which the direct path to the goal is barred, but in which an indirect path remains. The animal is placed in this situation which, as far as possible, must be absolutely obvious and clear. The experiment must show how far the animal is capable of employing the circuitous route.

A further complication of the same principle consists in introducing tools into the experimental situation. The circuitous route to the goal is formed, not by movements of the animal's own body, but by the aid of external objects which play the part of tools. It must be remarked that from this point of view the inclusion of tools into processes of behaviour radically alters the whole character of the behaviour, at once making it representative of the "circuitous route."

Köhler himself points out that instinct exists for the body of the animal, for the activity of its members, but not for the stick which the animal holds in its hand. Hence we can consider the animal's own movements directed to the purpose in view as instinctive, but not the complex movements performed with the tool. Where movements of the organs are replaced by movements of tools and become "mediate," we are confronted with an intellectual operation on the part of the animal. At the same time we have a second very important criterion of intelligent behaviour, viz. the use of tools. This purposive application of tools in accordance with

the character of the situation is an objective indicator of the intelligent reaction of the animal, for the employment of tools presupposes an understanding of the objective properties of things. Finally, the third and last criterion for Köhler is the structurally integral, systematized character of all the operations performed by the animal.

By "structure" the new psychology understands integral processes that display a number of properties which cannot be deduced from the sum of the properties of the parts and that are distinguished by a number of laws applying only to the whole. The sharpest factual contrast between the mental operations of the chimpanzee and the operations arising from self-training by the method of accidental trials, consists in the fact that the mental operations performed by the chimpanzee do not arise out of separate elements that are formed in advance irregularly scattered among many others that have no relation to the situation requiring the movements. They do not arise from separate parts out of which the correct reactions are selected as a result of successful trial and which subsequently, by means of frequent repetition, are united into a single general chain reaction. The characteristic feature of intelligent reactions (operations) is precisely that they arise, not by the summation of individual parts, but immediately as a whole which determines the properties and functional significance of its component parts.

Köhler gave a brilliant experimental demonstration of this integral character of the chimpanzee's intellectual reactions. He showed that an isolated partial action entering into the composition of all the operations of the animal, looked at by itself, is

senseless and may even lead away from the goal, but in combination with others, and only in connection with them, it acquires meaning.¹

Of course, we who are materialist scientists and therefore supporters of the theory of evolution do not object to the application of data obtained from animals for understanding the elementary forms of human behaviour. In Köhler's experiments, however, we cannot help being disturbed by the excessive haste in drawing conclusions and also by the almost complete absence of statistical data such as we are accustomed to see in Pavlov's experiments.

Karl Marx long ago pointed out that the essential distinguishing feature of the constructional activity of animals (bees) in contrast to the constructional activity of man lies in the fact that an architect before building anything, and hence before employing building tools, first of all "raises his structure in imagination," *i.e.* works out his plan of action. Hence the question arises: Can it be said that the chimpanzee, on being "disillusioned" as to the efficacy of jumping, constructs a plan for obtaining the fruit involving the use of a tool—the stick? Köhler himself weakens his position by pointing out that when the monkey has once "discovered" the method of using the stick, it frequently afterwards attempts to use for the same purpose a handful of straw or even a feather.

A further important detail is this: chimpanzees sometimes learn to employ sticks for threatening one another, making very expressive gestures. But as soon as it comes to actual combat, the adversaries

¹ Quoted by Vygotsky in the Preface to the Russian translation of Köhler's book (1930).

immediately throw away their "tools" and use their teeth and fists in attack and defence. What a tremendous difference from human beings, in whom the whole history of material culture begins with the perfection of the stick, with the attachment to it of a stone axe-head to form a real weapon of attack and defence in the struggle against other animals. Hence what Köhler is inclined to call the invention of an instrument of labour seems to be more the result of his ardent desire to discover what he, as a professor of psychology belonging to the theological faculty of Berlin University, has to discourse on from his professorial chair, *i.e.* the origin of abstract ideas.

It can easily be understood that the conclusions drawn by adherents of the *Gestalt*-theory are very far from the order of thought characteristic of materialist scientists, from the order of thought of Pavlov himself.

The superiority of the method of *objective* study of animals lies in the fact that it makes possible not only the elaboration of theses but, above all, research into the actual facts. Pavlov, although not concerned with studying the part played by tools in the origin of man, nevertheless took the opportunity of a gift of two anthropoid apes from a Paris laboratory to set to work at the Koltushy Biological Station together with Denisov to test Köhler's experiments, reproducing them even to the smallest details.

Under the rays of the powerful physiological searchlight, supplied with energy derived from all Pavlov's preceding experience, light was gradually thrown on the neurocerebral web which wholly

determines the pattern of Köhler's "Gestalt" so clearly manifested in anthropoid apes.

The basic fact established by Köhler was in general confirmed, but its *meaning* proved to be essentially different and at the same time incomparably simpler; not a single phenomenon was discovered which was not previously well known to the creator of the method of conditioned reflexes.

Köhler's "whole" proved to be fully divisible into its component parts; the physiologist's answer to the nebulous "structure" of the psychologist is given by Pavlov in a very decisive form. He says: "I feel a strong repugnance to, and emphatically reject, any theory that claims to embrace fully everything comprising our subjective world, but I cannot refrain from analysing it, from obtaining a simple understanding of it at separate points. But this understanding must consist in bringing the separate phenomena into agreement with the data of our modern, positive, scientific knowledge."

In this passage, as in many others, Pavlov vigorously defends his beloved science—physiology—from the intrusion of outside idealist theories, even if masked as modern science as in the case of Köhler's experiments. It is only due to Köhler that one should mention that he highly values Pavlov's genius for experiment, and is ready to admit that the physiologists at the present time are making an approach to the same phenomena as he himself, only "from another aspect." Of course Pavlov has never in any way sought to prevent other methods of investigation, including the method of self-observation. In recent years, when the right of the physiologist to a comprehensive study of human

higher nervous activity has been universally admitted, Pavlov ceased to demand that a fine should be levied for the use of the word "consciousness." He habitually employed this word himself in relation to man. He recognized that the fragments of positive knowledge wrested from nature are very modest in comparison with the mountain of the unknown that awaits our analysis.

In our personal opinion, the next stage in the development of the work left unfinished owing to Pavlov's death must be research into the part played by labour and instruments of labour in the process of the ontogenetic and phylogenetic development of man, research into the connections between the highly complex *physiological* structures and the corresponding technical acts connected with the establishment of the real power of man over nature.

But equally essential is the study of pathological derangements of the human mind, so energetically pursued by Pavlov during the last years of his life, and a comparative study of the behaviour of lower and higher vertebrates. Finally, the study of the action of drugs, in particular those acting on the nervous system, on the animal and human organism is also called for.

"For scientists," says Pavlov, "everything lies in the method, in the chances of discovering irrefutable truth." In this sense one must regard the sphere of application of the method of conditioned reflexes as far from being exhausted, but rather as having been only exactly and correctly sketched out by Pavlov himself, leaving it to future generations of scientists to utilize to the full its tremendous power.

THE COMPARATIVE PHYSIOLOGY OF CONDITIONED
REFLEXES

During recent years the extensive school founded by Pavlov has been busy with what might be termed preparatory work for solution of the central problem, that of the distinction between the activity of the brain in human beings and animals. Thus, M. K. Petrova is studying the action of various doses of bromine compounds, caffeine and alcohol on the nervous system, and also the effect of removing the sex glands on the character of the higher nervous activity or temperament of animals; V. Fedorov and Lindberg are also devoting themselves to research on certain narcotic drugs; N. Podkopayev is investigating special forms of conditioned reflexes in which the connection with the phenomenon of association finds its best manifestation; Denisov is working out the laws of behaviour of anthropoid apes; F. Mayorov is determining the influence of artificial retardation of development on the higher nervous activity of puppies; Vyrzhikovsky is working on the laws of inheritance of certain characteristics of nervous activity. In all respects, the work is growing and extending.

One must not omit to mention certain new fields of research, the basis for which was provided by the field opened up by Pavlov but in which the latter did not himself participate, notably the work of N. Krasnogorsky and A. Ivanov-Smolensky on the higher nervous activity of children, a research which they have already been pursuing for more than a decade.

Finally, the experiments in Moscow of the author

and his collaborators on the higher nervous activity of various species of animals, beginning with fishes and birds and ending with monkeys, are creating a basis for the physiological analysis of *instincts* and other complicated forms of animal behaviour.

The comparative physiology of conditioned reflexes began with the study of the lower vertebrates. We were very much tempted to apply the new physiological method of conditioned reflexes to decide the question of the auditory capacity of fishes. This idea was the more attractive in that it was not so much a question of hearing in fishes but of whether fishes are in general capable of forming complex associations in their comparatively poorly developed brains, which lack the highly developed cortex of the cerebral hemispheres. Hence, in starting experiments on fishes, we felt that we were dealing with the very first beginnings of higher nervous activity. In fact, fishes form a remarkable subject for experiment; it is as if nature herself had made an experiment on the brain in these lowly representatives of the vertebrates, in depriving them of their cerebral hemispheres. We had the possibility here of determining whether an animal, faced with a more or less complicated task, could do without the aid of the higher brain centres and replace them by the activity of the lower-lying centres.

Naturally, we had no intention of performing our experiments in natural reservoirs, as had been previously done by Zondek, since it was a question not merely of the reactions of freshwater fish but also of working with representatives of the marine fauna. During recent years we have been able to carry out work at the Marine Biological Stations in four places,

viz. on the Baltic Sea, the Baring Sea, the Black Sea and the North Sea.

For performing the experiments we decided to construct a special electrically equipped aquarium in which we could produce various sounds at will. In addition we established a special signalling system, thanks to which we could accurately judge of the behaviour of the fish even without seeing it.

We began by taking an ordinary telephone receiver and fitting it into a narrow metallic holder; we arranged this apparatus so that it could be either let down in the water or lifted up so as to be above the surface of the aquarium.

To record the movements of the fish, we used a specially constructed signalling system based on the method of Marrey. Selecting a fish for the experiment, we passed a silk thread through its gill slits and fastened the thread on its back before replacing the fish in the aquarium. The other end of the thread was attached to a so-called Marrey capsule joined by a long rubber tube to the recording apparatus. Any movement of the fish drew the thread with it and thus opened the bottom of the capsule and let air into it. This in its turn caused a downward shift of the writing point, which wrote on the surface of a moving drum.

It was found that all fishes without exception, whether marine or freshwater, very quickly became accustomed to their new surroundings when placed under these rather artificial conditions and remained quiet, in spite of their movements being somewhat restricted, which was a matter of very great convenience for the experimenter.

It remained now to connect the sound produced in

the aquarium with definite movements of the fish, in other words to evoke in the fish a conditioned reflex or association between the auditory stimulus and motor effect.

To what can the fish respond by its movements? Of course, only to something that enables it to acquire food or avoid danger. These needs are inborn in it, they are instincts or unconditioned reflexes. We decided to begin by making use of the current from an induction coil. This current, of medium strength, was passed through the water of the aquarium and consequently also through the body of the fish to which electrodes were attached, evoking in the fish instinctive movements of a marked defensive character.

Everyone knows from his own experience that if the conducting wires of the electric light supply are touched, especially with wet hands, a considerable shock will be experienced, causing one to remove the hands. Fishes, whose bodies are covered by fine scales, are also very sensitive to an electric current. In our experiment, this current was conducted directly to the scales of the head of the fish by means of a light metallic connection. Thus, the apparatus to which the fish was fastened was at the same time both a conductor for the current and an apparatus for signalling the movements of the fish, as described above.

It was found that if the sound of the telephone, given out under water, was reinforced by a short electric shock, the fish comparatively easily developed a response to the sound of the telephone. When this new connection in the fish's brain, viz. the connection between the sound and the action of the current,

had been established, it was possible to carry on the experiment for some time even without the help of the electric current.

The fish answered by marked movements as soon as the diaphragm of the telephone receiver began to vibrate.

The telephone apparatus was then gradually raised towards the surface of the water, not forgetting from time to time to accompany its action by electric shocks. Finally, the telephone was altogether removed from the water and left hanging in the air above the aquarium. In spite of this, the fish continued to respond by its movements to the sound given out, although the latter was emitted now in the air instead of in the water.

Our problem, therefore, was solved. A fish which in virtue of the structure of its sense organs is not able to hear sounds directly, *i.e.* sounds as a vibration of the air, can react excellently to sounds so long as they are propagated through the water in which the fish is lying.

The research described here was the subject of our report to the International Physiological Congress in Stockholm, and was also repeated by O. Bull in the biological station at Plymouth, where all the main conclusions were confirmed.

In his experiments, however, Bull employed as the unconditioned stimulus not an electric current but the reaction of the fish to food stimulation. It was found that fishes are capable not only of discerning such delicate differences as a rise of 1° C. in the temperature of the water, but also of appreciating very slight alterations in the salinity of the water.

After we had obtained these data, giving a com-

prehensive picture of the behaviour of the fish as far as brain reactions are concerned, we began to carry out operations on the fish, removing by means of a special apparatus separate parts of the brain or disconnecting entire organs (visual apparatus, linea lateralis, etc.) with the object of tracing changes in the higher nervous activity as a result of these operations.

We were able to convince ourselves that the highly valuable property of the animal to orientate itself under various conditions of the external medium could be attained by various means, and that animals living in water are as able to guard against accidents arising from their environment as we who rejoice in a subaerial existence. On the other hand, it becomes clear to us that the higher associative functions in animals are carried out by utilizing not only the cortex but also the structures which in the course of development of higher animals have been pushed into the background, viz. the so-called subcortical centres.

We cannot avoid touching here, even if only cursorily, on the problem of unconditioned reflexes in the lower vertebrates. Certain facts indicate that under definite external conditions some unconditioned (inborn) reflexes are retarded and sometimes may not be manifested at all. And this applies not only to the sex reflexes, which sometimes disappear under the conditions in which animals are kept in most zoological gardens, but also to other reflexes, in particular those connected with food.

We had occasion to observe a case in working with fishes (*Tinca vulgaris*), where repeated application of the electrical stimulus inhibited the food reflex for

the whole two years during which the extensive research was carried out.

In some old experiments on a comparison of the motor and salivary reactions in puppies, brought up on milk until six months old, I. S. Tsitovich succeeded in establishing the fact that while the motor reaction of the puppy to the smell of meat wrapped up in muslin is inborn, the secretory, *i.e.* salivary, reaction is entirely absent. In other words, every puppy has to elaborate the salivary reaction to the smell of meat during its lifetime.

As regards the *sight* of meat, which in this experiment was deliberately deprived of its specific odour, it was found that even the motor reaction demands preliminary preparation.

Hence, by employing a more delicate method than any used before of dual secretory and motor study of the reactions in a young mammal, we can convince ourselves that its motor reaction to an object of great importance for a predatory animal, *viz.* meat, is either inborn, if one judges from the reaction to smell, or acquired, if one judges from the reaction to sight.

Further research is being conducted on the comparative physiology of conditioned reflexes. In 1933, Asratian described a method of studying conditioned reflexes in tortoises, both conditioned and unconditioned reflexes being registered with great accuracy by means of appropriate indicators. The data accumulated by this method testify to its great value.

Studying conditioned reflexes in tortoises to tactile (mechanical) stimuli by means of his method, Asratian arrived at the following conclusions: A

positive conditioned reflex in tortoises is formed as rapidly as in higher animals, possibly even more rapidly than in many of them. Positive conditioned reflexes in tortoises are slightly more stable than in the other animals mentioned. The inhibitory processes in tortoises, however, are incomparably weaker than in higher animals. According to many of its characteristics, the conditioned reflex in tortoises occupies a middle place between the conditioned and unconditioned reflexes of higher vertebrates.

Chapter VII

PAVLOV'S THEORY OF EXPERIMENTAL NEUROSES

PAVLOV'S THEORY OF TYPES OF HIGHER NERVOUS ACTIVITY. THE INADEQUACY OF KRETSCHMER'S CLASSIFICATION OF TEMPERAMENTS

PAVLOV's researches, pursued during a long and fruitful life, followed in the main two directions, viz. the study of digestion and the study of higher nervous activity in animals. Viewing his work as a whole, however, one should add to these a third field of study, viz. that of nervous and psychical derangements in man.

On one of his visits to England, Pavlov was honoured by Cambridge University with the award of a Doctor's Degree, chiefly on account of the advances he made in the study of digestion by his work between 1878 and 1900. At the appointed hour the University Senate was filled with the audience who had come to hear Pavlov's lecture on this ceremonial occasion.

The University students, in accordance with an old-established tradition, decided to mark the occasion by presenting the newly-honoured guest with an appropriate gift. They selected for this purpose a simple toy dog which they stuck all over with small pieces of glass apparatus. Afterwards, Pavlov always kept this gift on view in his study.

However, the lecture delivered by Pavlov was not concerned at all with digestion but dealt with a completely new topic, viz. the study of *higher nervous activity in animals*.

In an exactly comparable fashion, in July 1935, the delegates to the Second International Neurological Congress in London assembled in the expectation of hearing from Pavlov himself something relating to the normal physiological activity of the brain as investigated by means of dogs.

But they heard instead a lecture of a completely new character, "On Types of Higher Nervous Activity in Connection with Neuroses and Psychoses," to a great extent based on data obtained by Pavlov from the human clinic. During the last few years, Pavlov devoted assiduous attention to clinical study. This example shows once again that Pavlov was always in advance of what was written about him in the encyclopædias, which contained old data and failed to keep up with the rapid development of his ideas.

Without giving up his laboratory work Pavlov gradually passed to this clinical study of neuroses and psychoses in human subjects. This was, of course, no accident. It had a long history behind it. To begin with, Pavlov had always been a physician, and not simply a clinician but a passionate searcher after truth who valued all his achievements, whether in the sphere of digestion or the study of cerebral activity, from the point of view of the benefit which his discoveries could bring to suffering humanity.

On the other hand, the enormous variety of peculiarities of behaviour in individual animals, observed every day in the laboratory and subjected to detailed

study by Pavlov, demanded some systematization if only to prevent oneself getting lost among the host of individual characters with which nature gradually began to overwhelm the attentive investigator into animal behaviour. Hitherto physiologists had made a study of only one animal, the dog, although it must be admitted this had been made with unprecedented fullness. The time had now come to extend the investigation and to continue the study on the plane of comparative physiology and pathology.

In this respect the laboratory has been, and undoubtedly continues to be, in advance of the clinic, which is also concerned with the analysis of complicated objects, viz. human personality. The extreme manifestations of individuality, however, proved to be better open to study in the clinic, and hence arose the connection of Pavlov's study of types of higher nervous activity of animals with the investigation of pathological manifestations of individuality as observed in the clinic for neuroses and psychoses.

This example of his latest study of types or temperaments most clearly shows how Pavlov, who always maintained a lively interest in all neighbouring fields of knowledge, including psychiatry, gradually entered into all details of the discoveries made in the clinic. He worked critically and creatively on the data obtained from the clinic, and gradually extended its basis to such an extent that very soon his discoveries outgrew the boundaries originally imposed by the authors and obtained greater renown than they had enjoyed among the clinicians themselves.

We have already observed something of this kind

in speaking of Freud's theories, which Pavlov as it were put right side up. We have now to speak of Pavlov's attitude to the theories of Kretschmer. The latter's book, *Physique and Character*, laid the basis for the modern theory of types of *constitution* of the nervous system correlated with the constitution of the body, and produced a great impression not only on clinicians but also on those more concerned with theoretical studies, especially physiologists dealing with higher nervous activity. In spite of the fact that the general character of Kretschmer's work is one that is absolutely foreign to us, many of us have been impressed by his clear artistic description of two contrasting types of mind, the cyclothymic and schizophrenic temperaments. At the same time the *obligatory* connection of these types with purely *external* structural features of the body always appeared to us somewhat suspicious.

It is noteworthy that this book led to a marked division of opinion among psychiatrists, whose views cause them to be regarded as the most conservative representatives of medical science.

This book of Kretschmer's, and particularly his two succeeding works,¹ were useful because they contained an attempt, albeit a timid one, to link up clinical studies with the physiology of conditioned reflexes as established by Pavlov. By his description of "extreme" types, Kretschmer constructed a bridge, perhaps a flimsy one but still a bridge, from the normal to the pathological, from the laboratory to the clinic.

Kretschmer further attempted to link up the activity of the brain and the study of temperament

¹ *Medical Psychology and Hysteria*.

with the activity of the endocrine glands and the autonomic nervous system. Finally, he expressed himself clearly on the physiology of emotion, and raised the question of the possibility of the liberation of the "lower, primitive mechanisms" in the absence of the cortical inhibition which normally kept them subdued.

At this time the theory of conditioned reflexes had already made considerable progress in regard to the question of types, and stood on the eve of new important generalizations.

As previously mentioned, during the period prior to 1914 we divided our dogs from a purely utilitarian point of view, according to their *external* behaviour, into lively (good) and sleepy (bad). Later it was found that dogs which outside the stand were reckoned as "lively," were most of all inclined to sleep just when we demanded that they should keep awake, viz. during the performance of an experiment.

We then began to select for our experiments such dogs as were sedate or even somewhat cowardly outside the stand but which never slept while on the stand.

The group of previous favourites, those animals active outside the stand, began to be regarded as especially valuable where it was necessary to form conditioned reflexes as rapidly as possible. Such dogs showed inhibition only with difficulty. At the same time they required that the experiments made with them should be continually varied, and if this was not the case they went to sleep.

It became necessary also to recognize the existence of a "middle" group of individuals, in which the

processes of excitation and inhibition were equally strong. Nevertheless, in those years this classification of types did not reach any sort of finality. Pavlov only emphasized the importance of studying the *constitution* of the cerebral cortex of the animal.

Some further years of intense work were required before this constitution of the cerebral cortex could be reduced to the *basic* properties of the nervous system, to the strength and balance of the fundamental cerebral processes. In this new stage we had to make the acquaintance of Pavlov's latest views on the *lability* and inertia of the tissues. Consequently, we now recognize three basic properties of nervous functions, viz. *strength*, *balance* and *lability*, which serve to classify "types" of nervous systems.

The main features of the problem of temperaments, from the point of view of Pavlov himself and of his school, can be depicted as follows: Primary and chief significance attaches to the factor of the *strength* of the neurones which determines the basic division of types of higher nervous activity into strong and weak. Provided the animals compared have been reared under similar conditions, the strength and endurance of the cortical cells can be compared by using the reaction of the animal to an excessive external stimulus, *e.g.* a klaxon, a rattle, theatrical thunder and suchlike agents. In so doing, tests are made whether these stimuli are capable of being linked up with the food stimulus according to the laws of conditioned reflexes. The formation of a reflex to strong stimuli serves as a kind of sign of the "boldness" of the animal or, what is the same thing, the working capacity of its nerve cells.

The opposite reaction, *i.e.* inability of the animal

to endure medium and even weak stimuli, which externally coincides with cowardly behaviour on the part of the dog, is a sign of low working capacity of the nerve cells and indicates an unfavourable cortical constitution in such animals. Hiding in corners with the tail between the legs is one of the external marks of such dogs. Even the ordinary strength of external stimulation proves to be above the maximum for them and leads to a state of inhibition.

The next principle furnishing a boundary line dividing types of higher nervous activity from one another, lies in the equality or non-equality of the basic nervous processes, *excitation* and *inhibition*, in other words the degree of balance between them. By inhibition is meant here the highest form, active or internal inhibition, as dealt with in the preceding chapters. We know that these two nervous processes are in a state of constant complicated interaction and mutual conflict with one another.

It would be possible to select a number of individuals displaying excellent reactions to strong stimulation, *i.e.* excellently capable of forming conditioned reflexes in response to strong stimuli, but nevertheless not able to elaborate any delicate differentiation of two stimuli or to form so-called delayed reflexes, not to speak of trace reflexes. If they do elaborate such reflexes it always requires obvious labour and occurs with protests and "complaints." The conditioned reflexes formed are marked by their unequal size. These dogs were defined as strong but unbalanced, and formed the unstable type of Pavlov, or the so-called choleric type, to use the terminology of the ancient Greek physician Hippocrates.

In the presence of other dogs it is easy to recognize such individuals by their behaviour; they quickly become involved in quarrels without taking heed of the strength of their adversary, they are usually quarrellers and consequently always go about with torn ears.

It might be thought that in accordance with this scheme it should be possible to find unbalanced individuals also at the other end of the series, viz. among dogs in which the process of inhibition predominates. At this end of the series, however, the weakness of the process of excitation is so great that at the best we get types like the dog Melya, described above. There can, of course, be no talk of balance in such dogs. This is the so-called "melancholic" type of Hippocrates, a type which is not a great favourite of the experimenter, since in such individuals conditioned reflexes are formed only with difficulty.

Let us pass to the medium, balanced type. The existence of an *equilibrium* between the two nervous processes, the capacity equally well of giving reflexes and of suppressing or retarding reactions to external stimuli according to the requirements imposed by other equally important stimuli, constitutes the important condition for the perfection of this type. Such dogs are very well able to tolerate the formation of differentiations.

A characteristic of this type of higher nervous activity is its capacity actively to respond to selected stimuli of the external environment and at the same time to respond with very great reserve to strong stimuli which do not lead it to the desired goal.

But strength and balance are still not sufficient

for us to regard the type possessing these alone as perfect. Balance undoubtedly greatly increases an animal's chances of survival. The external environment, however, is a complicated mosaic of active and inactive stimuli and does not remain unchanged during the whole life-cycle of the animal. Even elementary seasonal variations of the environment make demands on the nervous system of the animal, even on a strong and balanced nervous system, which involve continual *reconstruction*, the ability to deal with changing situations. That which today may be an active stimulus imperatively demanding a reaction from the animal may tomorrow have to yield place to another more active stimulus and itself be subjected to inhibition.

We know that the environment surrounding the animal varies in time, not only according to the season but also month by month; sometimes it becomes transformed in the course of a single day—and both nervous processes, excitation and inhibition, must cope with these variations. In other words, they must possess a high degree of lability and be able to give place to one another in time at the first demand. Only then will the existence of the animal be adequately protected.

It is possible to find any number of individual animals which differ from one another in regard to lability, although they are all strong and balanced and with good working capacity. While some representatives of the strong, balanced type are reactive, excitable and rapid in their responses, others, equal to them in point of endurance, are somewhat slow and extremely staid.

Pavlov applied Hippocrates' term "sanguine" to

the former variety of strong, balanced dogs, while the second he referred to as "phlegmatic." Both varieties are fully capable of maintaining their existence, both are to be found among wild and domestic animals. Everywhere they occupy the first place. Nevertheless, their value is by no means equal.

While the sanguine type of dog strikes us during an experiment with conditioned reflexes by its "business-like" attitude on the stand, maintaining always a concentrated but unconstrained pose, and while such a dog is easily able to cope with delayed conditioned reflexes and even the transformation of active stimuli into inactive ones and vice versa, the phlegmatic type, although it is able to endure prolonged inhibition, nevertheless categorically refuses to make any reconstruction of the reflexes once elaborated in its nervous system or to attempt to change the form of a so-called "stereotyped" reaction.

It was to this latter type that our dog Prima belonged, which was spoken of above in connection with the formation and destruction of elaborate complexes in the brain.

On the basis of tremendous laboratory experience, Pavlov in his latest works drew conclusions as to the frequency with which the different types of animal are encountered. According to his authoritative opinion, the most frequently found types among dogs are the weak melancholic type and the balanced, labile (sanguine) type.

The impetuous, choleric type is less frequently met with, and rarest of all is the balanced and *inert*, *i.e.* phlegmatic type. It may be noted in passing that in the wild and semi-wild state, as far as we

have been able to obtain data, the above conclusions must necessarily undergo considerable modification.

The fundamental advantage of this classification in comparison with others, including Kretschmer's, is that Pavlov has based it on detailed study of the *course* of the nervous processes and that he takes a dynamic view of the question of types. Further, he does not try to force all possible varieties into the bounds of his four types. Pavlov took fully into account the artificial character of *any* classification of individualities, stating: ¹

"Leaving gradations out of account and considering only extreme cases, the limits of variation of the two processes, viz. strength and weakness, equality and inequality, lability and inertia, we already have eight combinations, eight possible complexes of the basic properties of the nervous system, eight types of nervous system. If we add that in the case of lack of balance the predominance may, generally speaking, be on the side either of excitation or of inhibition, and that in the case of lability also the inertia or lability may be a property sometimes of one and sometimes of the other process, the number of possible combinations already reaches 24. . . . However, only careful and extensive observations will establish the existence, and the frequency or rarity of these and other *actual* (our italics, Y. F.) complexes of basic properties, of the actual types of nervous activity."

This is why Pavlov expressed himself against the extreme views of Kretschmer and his followers. He said: ¹

¹ Pavlov, *Latest Communications on Higher Nervous Activity* 1935 (Russian).

“Kretschmer’s classification of nervous types, which has obtained almost universal recognition, especially among psychiatrists, must be regarded as mistaken or inadequate.”

Pavlov, therefore, expressed himself against compressing all the wealth and variety of physiological types encountered in actual life into the Procrustean bed of Kretschmer’s classification, which is based on far from complete clinical data that are inevitably restricted by the narrow bounds of place, time and biological and social conditions under which clinical investigations are usually conducted.

THE FLOOD OF SEPTEMBER 23, 1924, IN LENINGRAD,
AND THE RUPTURE OF HIGHER NERVOUS ACTIVITY
IN THE EXPERIMENTAL ANIMALS

We shall pass now from the study of types of higher nervous activity to the study of the rupture of higher nervous activity, by which Pavlov understands both complete and partial *breakdown* of the cortical mechanism under the influence of complex external actions, and all the consequences arising therefrom.

For analysing the behaviour of the animal as a whole, it is insufficient to determine the animal’s type of nervous activity. It is essential to study attentively the special features of the environment in which it passes its life. It is necessary to know not only what connects it with the environment but also what in the latter stands in opposition to it. In short, it is necessary continually to bear in mind not only the connection but also the possible *discord* between the individual and its environment, and to study the forms

and intensity of the reaction of the nervous system to this discord.

In speaking of experiments with animals, we have in mind discords characterizing the relation between the animals and natural objects and phenomena occurring under both natural and artificial laboratory conditions.

What means does a physiologist have at his disposal to destroy experimentally the active balance between excitation and inhibition that represents a precondition of the fully normal functioning of the brain.

We possess several different means for destroying this normal activity. In the first place, it is possible to attempt to *switch over* the arc of one unconditioned reflex on to the path of another reflex. Sometimes this switching over proceeds smoothly, sometimes it does not. In this connection we should recall a detail mentioned in the description of Yerofeyeva's experiments: when the stimulus of the electric current, which had already been elaborated as a conditioned stimulus for producing the food reaction, was shifted to ever new places on the skin, the time came when the behaviour of the dog suddenly and sharply altered. Not only did the conditioned food reflex that had existed so far during the experiment suddenly disappear, but the animal began to try to escape from the stand, endeavouring to avoid the stimulus, a thing that had not happened before. It is clear that the inhibition of the pain reflex previously attained by us had become incompatible with an irradiation of opposite sign, *i.e.* of the excitatory process, over the whole mass of the skin analyser. As a result there took place this

change in the higher nervous activity which was subsequently entitled *rupture*.

The second means of attaining this rupture is to produce in the cortex two foci of processes that are more or less restricted, situated side by side and of equal strength but of opposite sign—positive and negative conditioned reflexes. This includes, for instance, the contrasting of differentiated stimuli, active and inactive, the contrasted stimuli following immediately after each other (Rozenkov). A third means is to pass beyond the boundary of the analysing activity of the animal in regard to its capacity to distinguish between closely similar but not identical stimuli. This phenomenon was observed in Shenger's experiments mentioned above.

A fourth means of obtaining rupture is the conversion of a negative conditioned stimulus into a positive one, in which case the processes in the nervous system encounter great difficulties (Rikman). Here one can observe the same transitory phases between sleep and the waking state that were described by Rozenkov (Fig. 19).

Finally, there is a fifth method, viz. to produce a marked focus of excitation or inhibition in the brain by what is well known under the name of psychic trauma or shock.

What are the detailed symptoms of such rupture? These have now been elucidated fairly completely. In the first place, we know that the behaviour of the animal undergoes a marked change; it suddenly refuses to enter the chamber where the experiments are conducted and, on being brought in, it begins to whine and sometimes even to bark furiously. One observes in regard to conditioned salivary reflexes in

strong but unbalanced animals the abolition of differentiation and other inhibitory processes. It is not only the delicate but also the most coarse differentiations that suffer. On the other hand, in animals belonging to the *weak* type it is the processes of excitation that suffer, the elaboration of reflexes, and hence all work with them, becoming a matter of great difficulty.

In all these cases one observes the various phase changes of excitability; the paradoxical and other phases characterizing the transition of the nervous system from the waking to the sleeping state and vice versa, make their appearance. It should be mentioned that these symptoms sometimes appear immediately after the conflict between the processes that results in rupture, while sometimes they appear only on the second or third day.

An analysis of these cases led Pavlov to the physiological solution of the problem of the origin of *neuroses* in man, and in this connection he noted the very close relation between the theory of rupture and the theory of *individuality*.

The origin of rupture most frequently lies in a conflict between the two processes of excitation and inhibition. There are always sufficient causes for the formation of foci of excitation in the cortex; they are formed especially frequently as the result of so-called emotions taking part in the functioning of the cortex, such emotions being characterized by an extremely wide extension of excitation over the whole cortical substance. In addition, every conditioned reflex adds something to the processes of excitation.

What is the source of the inhibition that so persistently comes into conflict with excitation? It has

two sources : on the one hand, inhibition arises as the consequence of *powerful, but comparatively brief, stimulation*, such as, for instance, a sudden shock, a fire or some other stimulus which may completely or partially benumb the animal owing to the nerve cells being stimulated beyond the limits of excitation. This produces an inhibition which has been given the name of ultra-boundary inhibition.

It was this kind of inhibition that took place among the experimental animals of Pavlov's laboratory during the remarkable floods of September 23, 1924, in Leningrad. Water unexpectedly penetrated into the building where the feeding-room of the dogs was situated. The laboratory attendants hastened to the rescue of the animals. Each dog was of account and was highly prized because of the important work in which it had been used for several years.

The animals were kept in low cells with doors situated close to the floor. When the attendants arrived in the feeding-room, the cells were already at least two-thirds full of water. The water had forced the dogs to the ceiling of the cells; they were floundering about or swimming in the water but there was no way out.

It was by no means easy to rescue the animals. They stubbornly resisted, and no wonder, for it was necessary first of all to submerge the dog's head under water in order to drag the dog out through the opening at the level of the floor. The majority of the animals had great difficulty in enduring these experiences.

All the dogs were saved, but as a result of the flood some quite exceptional consequences were observed in several animals. Pavlov's collaborators,

A. Speransky and Rikman, noted that after the flood conditioned reflexes to ordinary stimuli, such as light or sounds, had disappeared. It was as if they had never been formed. Only very gradually by means of numerous repetitions was it possible to restore these reflexes. But the matter did not end there. It was found that if a powerful electric bell was used as a conditioned stimulus with one of these dogs that externally seemed completely normal, the dog, which prior to the flood had given a good reflex to the bell, now reacted to it in quite a different fashion. As soon as the bell sounded, the dog became strongly agitated; it began to glance around as if it wanted to run away. But the most remarkable feature was that all the other conditioned reflexes that had only just been restored now once more disappeared for a long time. It was as if the whole higher nervous activity of the dog's brain had been shattered.

Gradually Pavlov came to the conclusion that the powerful sound, precisely because of its strength, was equivalent to a restoration in the dog's brain of the experience of the flood. In some way the bell reminded the dog of the flood although, of course, during the flood there had been no sound of any bell. The simple fact was that the dog had ceased to be able to bear strong stimuli, just as sick persons, neurotics, are unable to bear them.

The question was only finally cleared up, however, when Pavlov, who untiringly concerned himself with the fate of the dogs that had been saved, decided to perform a special test experiment. A second "mock" flood was specially arranged in the laboratory. For this purpose a stream of water was arranged to flow

under the door into the chamber where the dog was on the stand. As soon as the dog noticed the stream of water trickling along the stone floor, it fell into extreme agitation. It began to pant, it yelped and trembled, and the experiment ended with a renewed impairment of the dog's nervous system. Pavlov termed this illness *experimental neurosis*, i.e. a functional weakening of the nervous system produced by artificial means.

On the other hand, experimental neurosis can be produced by the chronic and repeated action of inhibitors such as we established in experiments on differentiation and which, while at first not of marked intensity, gradually prepare the basis for stable foci of inhibition. These foci subsequently come into conflict with the foci of excitation. Then there arises the previously described type of rupture due to the overstraining of the inhibitory process, such as occurred in Shenger's experiments on the differentiation of the circle and ellipse.

We must mention also cases of the influence of internal "disorders," where weak, trifling stimuli, little by little, imperceptibly but continuously, succeed in taking the place of inhibitory foci in the brain and finally come into conflict with other foci. We will give just one example of this kind.

On one occasion the work with the dogs was carried out under very difficult conditions. The food conditions, it is true, were satisfactory, but the others, such as temperature of the air, sanitary conditions, etc., were very bad. Nevertheless, some of the dogs worked satisfactorily even under these conditions and gave reflexes and differentiations.

One of the dogs, however, which had a weaker cortical constitution, began gradually to break down after several months of work; its working capacity steadily decreased so that experiments could only be made with it at intervals of one and later two days. Finally the matter went so far that it could only work satisfactorily once in a month. On being transferred into another building, this dog returned to normal and began to work satisfactorily. Many such examples could be given.

There is no doubt that so-called neurasthenia has much in common with the rupture of higher nervous activity as described in physiological literature. Even in individuals with a strong nervous constitution definite symptoms of the breakdown of the higher cortical centres can be produced, provided that intense or irregularly acting stimuli are applied.

The basic fact, which Pavlov had also emphasized previously, is the following: every time that a stimulation of the cerebral cortex is produced, in this particular case with the formation of a conditioned reflex, the corresponding cerebral cells or groups of cells receiving the stimulation inevitably undergo a certain exhaustion or fatigue.

On the other hand, it is well known that the healthy brain is able to perform tremendous work and to cope with very important tasks without any perceptible signs of fatigue.

As already mentioned, the crux of the matter lies in the fact that the cerebral cortex among its other remarkable qualities has the capacity for forming foci of excitation at some points while other points are in a state of sleep. Thanks to the switching over of these processes, the separate elements of the cortex

are able to recuperate during the very period when the brain is working.

According to Pavlov, so-called general or natural sleep is to a large extent not a sign of the *onset* of fatigue, but a preventative of a possible exhaustion of the nerve cells. The normal brain has a very great capacity for work, the resources of the nervous system being not at all easily exhausted. The nature of the brain, however, by putting forward the factor of inhibition, as it were warns the organism of possible exhaustion, of the fact that the limit of the particular stage of activity is being approached. It is, of course, always possible to exceed this limit, *i.e.* to combat sleep even when it legitimately approaches. Sleep may be fought off for two or three whole days, but subsequently the price must be paid. This price may find its expression in the fact that the over-excited brain loses its capacity for inhibition, giving rise to what is commonly called *sleeplessness*.

In all such relations the previously mentioned reflex to *time* plays a very important part. It is well known that the central nervous system is subjected to special difficulties by *irregularity* in working, lack of system and the absence of a regular routine. This is the reason that, in man, labour and rest should regularly follow one another. The period of daily rest need not necessarily be spent in complete inactivity. It should ensure the *switching over* of the energy from those centres that were occupied during work to other centres that previously remained free. By observing these conditions, with a suitable organization of labour, the work of the brain can proceed uninterruptedly and productively for many decades.

THE DEVELOPMENT OF PAVLOV'S THEORY OF NEUROSES:
THE PARTIAL TRANSFERENCE OF RESEARCH TO
THE CLINIC

It is obvious that working with a human being during illness is a much more complicated matter than the study of animals such as had previously been the subject of observation by Pavlov. Man, as a social being, who has the power of speech and using tools, is governed in his development by incomparably more complex laws than those which regulate the activity of other primates, not to speak of the dog, the chief object of all the preceding physiological investigations.

Before passing to Pavlov's theory of neuroses in man, it is necessary to say a few words in explanation of the meaning of the word *neurosis*, and to give a short account of the history of this clinical term.

The term *neurosis* appeared in medical practice and literature more than a hundred years ago, being used to denote all those derangements connected with the sphere of the nervous system in general. Subsequently, however, with more accurate conceptions of the activity of the *separate* parts of the nervous apparatus, the term "neurosis" began to be used to denote those disorders which, while not being based on any perceptible organic defect, such as destruction of the integrity of the brain cells, nevertheless had a pernicious influence on both the bodily and psychical health of the patient. Eminent psychiatrists of the last and present century have emphasized sometimes one, sometimes another aspect of this characteristic derangement of the nervous system, as for instance the unusual *suggestibility* of

neurotics, the impairment in them of correct mutual relations between the higher and lower parts of the nervous system, as also the exhibition of reactions normally characteristic of only the *early* stages of individual human development. Finally, as the cause of neuroses they pointed to various kinds of internal *conflicts* observed in man—the conflict of mutually exclusive emotions, such as the sense of duty and the feeling of love, etc.

With the appearance in America of the new term “neurasthenia,” which was connected with the *excessive fatigue* or exhaustion of the nervous system, the idea of the connection of so-called *general neuroses* with the destruction of the nervous regulation of *particular internal organs* of the body underwent an extreme complication. From this time on, the term “neurosis” began to be used to denote two essentially different things. On the one hand, it began to be applied to numerous disorders in the functioning of the *internal organs*, such as giddiness, vomiting and other symptoms having a periodic or regular character; all sorts of derangements of the circulation, also temporary but nevertheless extremely unpleasant, such as sudden reddening or paling of the skin; symptoms of perspiration, excessive sensitivity to cold and heat, trembling of the fingers, sleeplessness, and finally a number of sexual disorders, including impotence, etc.

On the other hand, physicians became acquainted with a number of derangements which were, of course, definitely connected with the foregoing organic disorders but which had their independent significance. These slight but unpleasant derangements were extremely vexatious to the patients.

We have in mind here first of all the impairment of *memory*, for instance loss of memory for names, persons and figures; lack of concentration or its opposite, viz. excessive concentration on petty objects, such as exclusive attention to particular objects, like counting the windows in houses or the number of steps taken, etc. Included here is the development of sleepiness, excessive suggestibility or, on the contrary, a spirit of *contradiction* in the patient and finally *over-anxiety* and fear of falling ill from particular diseases. All these symptoms, taken together, led to an alteration in the character of the patient, with loss of interest in life, isolation from the society of other people, lowered productivity and skill, and many other unpleasant consequences.

However, these two groups of derangements in the activity of the organs, the first depending on a pathological state of the bodily organs and the second comprising a group of pathological symptoms depending on disorders in the activity of the higher centres, have remained until quite recently very little connected with each other.

In part, this lack of connection, which adversely reflects on the success of treating neuroses as functional nervous diseases,¹ has depended on the fact that physicians who have been insufficiently acquainted with the internal connection between the processes belonging to the two groups, have frequently put one in contrast to the other instead of finding the unity underlying these contradictions. This unity of functions should especially attract attention in

¹ As opposed to organic nervous diseases depending on defects in the structure of the nervous system.

the human organism where the activity of the cerebral cortex predominates over all other functions to a greater extent than in other animals.

We have pointed out that Pavlov during his observations carried out on an enormous number of experimental animals—both young and old, healthy and sick, with undamaged cortex and entirely lacking it—came upon numerous very interesting facts which enabled him not only to draw a conclusion as to the very close connection between the two above-mentioned groups of symptoms, but also to elucidate the fundamental physiological mechanism of neurosis, to establish the *gradual* character of the development of its separate symptoms, to determine its depth, to divide its course into separate phases, and finally to make clear the conditions for the return of the organism to normal. In short, Pavlov succeeded in his latest work in building a firm bridge between the modern physiological laboratory and the modern neurological clinic, the consequences of which in the form of positive results were not slow in appearing.

The conflicts between various unconditioned reflexes or emotions, more than once referred to above, have a counterpart in the conflict of opposing processes in the cerebral cortex, whence pathological derangements spread to the lower-lying centres. This factor is very important and, properly speaking, is the basis of neurosis.

However, it should not be thought that the lower-lying centres, that perform the important functions of regulating the activity of all internal organs, are in such cases of the development of neuroses only passive participants in the process, or the substratum

on which the influence of the cortex is exercised. The cortex and subcortex can mutually influence one another to an equal degree. Rikman's interesting experiments showed that every change in the functioning of the lower centres that control the life and nutrition of the internal organs and tissues, for instance hunger, immediately produces a corresponding change in the activity of the cortex.

We have also pointed out that in such cases the cortex falls into a special state which is akin to the previously described paradoxical phase and which in certain conditions can end by a complete *distortion* of the relations between the organism and the surrounding world. For instance, it is well known that a patient suffering from a derangement of the functions of the stomach or heart may conceive an aversion to the whole world. With the ending of this derangement, the patient's former disposition returns; in other words, the normal activity of the cortex is restored.

This is not what happens when the cause of the disease lies in the brain itself having been weakened by the action of *rupture* or by the influence of some disease or poisoning of the organism. Those *paradoxical* relations, which we mentioned above as transitory phases in the process of going to sleep, sometimes become the regular though abnormal state in the nervous system. Normal stimuli which go to make up the usual interests of the human organism—concern about food, care for cleanliness and for obligations to society—begin to weaken, while feeble, usually imperceptible, stimuli in the form of all sorts of superstition (as about "lucky" and "unlucky" numbers) begin to occupy the foreground. The

heightened suggestibility of the brain touched by disease, into which unwelcome inhibition has obtained entrance, passes into *self-suggestion*, the person becoming imbued with the most morbid ideas, for instance the conviction that he is developing some disease which actually is quite out of the question.

Hence a vicious circle is created; various changes in the activity of the centres concerned with nutrition, blood circulation, etc., produce an abnormal state of excitation or inhibition in the cerebral cortex, and the latter in its turn sends out abnormal signals to the lower brain regions and thence to the functioning organs. Thus a pathological state of neurosis develops, the higher nervous activity and the lower but very important centres that regulate the functions of the whole organism becoming linked up by strong but in this case abnormal bonds. A sort of tangle is produced, the beginning of which is frequently lost under the later layers.

How is this tangle to be unravelled, how is the person to be aided to extricate himself from such a state? To answer these questions it is necessary first of all to study closely the functions of the nervous system by an objective method, both as regards their higher and their lower parts. Then, after studying these functions, it is essential to apply the data obtained *to increasing the vital stability of the whole organism* by ensuring that the patient obtains a correct view of the nature of his illness, *i.e.* the application of what is called psychotherapy. In this respect tremendous significance attaches to *training the higher brain functions* which, as is evident from what has been said, play a very great part in maintaining the well-being of the whole organism.

Neuroses can be overcome by the same means as those through which they become installed in the organism, that is to say by creating new, more beneficial, cerebral connections. For this purpose, of course, the physician must have scientifically tested means at his disposal, the material for which can be drawn from Pavlov's experiments on conditioned reflexes. Switching over, rest, cure by so-called natural forces—air, water and sun—as well as certain special medical treatments, hot and cold douches, electrical treatment and, finally, certain drugs such as bromides in particular, all these things have a profound physiological significance. In his last years, Pavlov was very interested in the applications of bromide, and made use of this drug in various doses and in various cases of illness, obtaining very promising results.

PAVLOV'S VIEW OF CLASSICAL NEUROSIS—HYSTERIA

We now come to the analysis of one of the classical neuroses in human beings, viz. hysteria. It is hardly possible to name any other disease which has aroused so many disputes, or any other nervous derangement to which so many clinical researches have been devoted.

From ancient times, men were acquainted with a characteristic complex of symptoms which was connected, as its name implies, with certain abnormalities in the sexual sphere (*hysterus*=womb). All kinds of powerful experiences, however, such as those undergone during wartime, have provided a large number of cases of hysteria unconnected with sex.

Such eminent scientists as Charcot, Bernheim, Claparède, Ziehen, Pierre Janet and Kretschmer have made an analysis of this characteristic illness such as might be thought exhaustive. Nevertheless a modern psychopathologist, Hoche, recently declared that in spite of all successes that had been achieved, "in hysteria we are still facing a locked door."

When this remark of Hoche came to the knowledge of Pavlov, it acted as a challenge to him to mobilize all his energies for a last great battle against the ultra-conservative views of psychiatrists on this question. It stimulated him to make a final summing up of all the wealth of data which he had accumulated in the recent period in the laboratory and clinic. As a result we have now a very important and interesting document of Pavlov's, entitled *An Attempt at the Physiological Understanding of the Symptomatology of Hysteria*. This paper was written by Pavlov in 1932, and represents a trial excursion into the sphere of psychiatry on the part of a physiologist.

Pavlov first of all establishes the fact that hysteria is a disease "belonging mainly to the higher section of the central nervous system and especially to the cerebral hemispheres." It represents the result of constitutional weakness and temporary exhaustion of the nervous system.

This substantially confirms the view held by many investigators before him, *e.g.* Pierre Janet. But Pavlov's merit lies in the fact that he went much deeper than the psychiatrists into the analysis of the *internal connection* between the cortex and sub-cortical centres in the brain of hysterical patients, a subject which Kretschmer could only hint at.

While even excessively powerful stimuli are hardly dangerous as long as the cerebral cortex is strong and healthy, and while the normal activity of the cortex always restrains the activity of the subcortical centres, only at times freeing the latter for the performance of strictly defined functions, in hysterical patients, on the other hand, it suffices to make use of only a slightly strong stimulus for the excitation of the cortical cells to reach its limit or even to *exceed* it. This takes place because the functional resources of such weakened cells are very small. The cerebral cells of a hysterical patient have hardly come into a state of excitation before they become incapable of work. A normal cell does not quickly become subject to what can be called ultra-boundary inhibition, while in hysterical cases this danger is an immediate one all the time.

If ultra-boundary inhibition has once arisen in the brain of a hysterical patient, it spreads over the whole cortex and stops its activity. But this inhibition of the cortex, according to the law of positive induction, produces a surplus excitation in the "adjacent sub-cortex," *i.e.* it *sets free* all the numerous functions connected with the subcortex such as have already been mentioned more than once.

In cases where this state has not yet gone too far, this results in a permanently heightened *emotionality*, which Pavlov regards as the *first* sign of hysteria.

The vaso-motor centres thus set free cause flushing of the skin, which becomes covered with spots, and may even produce an extravasation of blood at the place of trifling injuries (so-called stigmata). The excitation of the cardiac centres results in an increase in the frequency of the heart-beat, while the

muscles give various combinations of convulsive movements, causing the patient sometimes to act like a circus clown. The result is the so-called *affective outbreaks* so characteristic of hysterical cases.

This, of course, in its turn, by means of induction (this time negative induction) exerts a tremendous influence on the cerebral cortex, which even without this is in a state approaching ultra-boundary inhibition, and causes it to pass into the paradoxical phase of activity. This results in the second main symptom of hysteria—the extreme *suggestibility* of hysterical patients.

We already know the nature of suggestion in normal, and to some extent also in pathological, cases. In hysterical persons, however, this suggestibility may exceed all limits.

On the basis of his experiments and clinical observations, Pavlov recognizes that the same abnormal relations that exist between the cortex and subcortex are to be observed in hysterical cases in the sphere of the mutual relations between the *second* and *first* signalling systems. The hysterical person does not lose the sense of reality and may even utilize his illness so as to derive advantages for himself from it.

The most important consequence of Pavlov's theory of the development of hysterical symptoms consists in the fact that the physiological understanding of these symptoms opens up far-reaching prospects of achieving a cure by means of correct *education* of the disordered nervous system, by giving the nerve cells complete rest, etc.

Besides such generally recognized pharmacological means as the use of bromine compounds, the dosage

of which has now been radically altered by Pavlov on the basis of his researches, Pavlov has advanced a number of rules for the care of such patients, a number of new introductions which will undoubtedly soon come into general use, just as Pavlov's method of treating patients suffering from disorders of the digestive tract has now become standard practice.

A CASE OF TWENTY YEARS' SLEEP AND PAVLOV'S ANALYSIS OF IT

In dealing previously with the subject of sleep and its forms, no hint was given that sleep could sometimes persist not merely for days but even for months and years. Such sleep, of course, is not normal sleep; it is a sign of an extreme derangement of the whole nervous system. Nevertheless it is important to make a detailed analysis of such cases whenever they occur.

This was the view held by Pavlov himself, who in 1918 while visiting the psychiatric clinic came across the case of such an illness that had lasted twenty years. Such cases of prolonged sleep have been observed more than once and have been given the name of *lethargy*, but this particular case was of exceptional duration.

The question naturally arises as to how life was maintained. The patient was fed artificially with liquid food through a flexible tube inserted into the œsophagus. This food was passively digested by him. The only sign of life observed by the physicians who treated him, apart from a weak pulse and weak shallow breathing, was the appearance in his stomach at the moment of giving food of a considerable

quantity of gastric juice. Apparently this "living corpse" still had some bodily functions which manifested themselves rhythmically.

The relatives of the patient, who had not deserted him during his illness of more than two decades, brought him oranges and the juice was poured into his half-opened mouth. The patient swallowed the juice but gave no other signs of life.

When Pavlov came to the clinic, the patient was about 60 years old; he had been in this state since the age of 40. It is interesting to note that Pavlov did not regard this case as one of the *organic* diseases, which, like locomotor ataxia, are incurable, but as a form of neurosis, *i.e.* a *temporary functional* derangement, such as those mentioned above, and consequently fully curable, although in this case the period of illness exceeded all limits hitherto known.

This case of sleep was only superficially remarkable. Even under normal conditions everyone knows of cases where a person who has requested that he should be woken up at a definite time begins to protest aggressively when his request is fulfilled. That is to say he exhibits inhibition in the motor sphere, so-called intoxication by sleep. The inhibition, having effected entrance owing to one cause or another into the brain of the patient, becomes concentrated mainly in the motor sphere, or, more correctly speaking, in the motor analyser. Thereby both the direct and reverse connections—in the sense of Miller and Konorsky—become paralysed and the person has no desire to wake up although some of his sense organs can function relatively well.

In his views given at the bedside of the patient, Pavlov based himself on what was at that time the

only known case of the *second* phase of sleep, that in the dog which had accidentally gone into a state of *catalepsy* on falling asleep while waiting for the experiment (see the description given previously).

Lethargy and catalepsy are closely connected with one another. Our patient was apparently in this second phase of sleep, when the impress of inhibition lies especially heavily on the motor sphere. One had to wait for his awakening to be able to cross-examine him as to the details of his life during this lengthy period.

But how long was it necessary to wait? This no one knew. Then, however, there came to the aid of the clinicians the advent of *old age*, bringing with it decreased reactivity, *i.e.* decreased sensitivity of the brain to all external and internal stimuli.

It is well known that normal physiological old age is accompanied by considerable weakening of *inhibitory* processes, which is the basis for the appearance of so-called senile talkativeness, fantasies and sometimes also feeble-mindedness. In the case of our patient this weakening of inhibition had a particularly favourable effect; it was as if the heavy fetters on the motor analyser had been removed. The patient began of his own accord to open his eyes, to move his tongue, to breathe more deeply and even to change his position in the bed, etc. Finally, matters went so far that he asked for food.

The time, it seemed, had now come to question him as to who he was and whether he remembered what had happened to him when he had gone to sleep, etc.

It was found, however, that under ordinary conditions, *i.e.* in daylight, the patient was not in a state

to answer questions; the physicians noted that such patients only take notice of their surroundings at a period when complete quiet reigns in the hospital, that is to say approximately just before dawn, when even the most restless patients are asleep. For the rest of the time our patient lay with closed eyes. It is evident that the *weakness* of his nervous system was such that stimuli appearing normal to us were for him of excessive strength, *i.e.* they put the motor centres into a state of inhibition.

And it was actually the case that when the patient was questioned during the early hours of the morning, he answered many questions and did so quite sensibly. (This observation has since been confirmed in other patients.) It turned out that during all these years the patient had heard and understood much of what had gone on around him, *e.g.* he recognized the physicians and his relatives who came to feed him. But he could not move a single finger;—it was always as if some insuperable weight held back his muscles from action.

Gradually he began to feel better, he began to eat unaided, to get up and walk about. Finally, he was discharged from the hospital.

This case reflects as in a mirror the whole of Pavlov's theory of neuroses. Neuroses, as the expression of extreme weakness of the cerebral cortex, are accompanied by extreme and prolonged inhibition that sometimes establishes itself for a long time within the limits of the motor analyser. This episode that we have recounted shows better than anything else how *imperfect* are our clinical notions of brain diseases and what a complex course is sometimes involved in their recovery.

Pavlov was always especially cautious in selecting expressions for his ideas when it was a matter of applying experimental data to human patients observed in the clinic. We give here an account in Pavlov's own words of his latest results obtained from the study of human neuroses :¹

"The fact can be noted that, thanks to the two signalling systems and in virtue of various forms of life that have operated from of old, the mass of human beings can be divided into artistic, thinking and intermediate types. The last named combines the work of both systems in the requisite degree.

"In the case of our animals, we continually found that chronic pathological disturbances of the higher nervous activity in the form of neuroses very easily made their appearance under the influence of means causing illness in two types, viz. the specially excitable and impulsive type and the weak type. Impulsive dogs are almost completely lacking in inhibition, weak dogs altogether refuse to give conditioned reflexes or at the most they give them in a chaotic form. Kretschmer, who limited himself to only two *general types*, corresponding to our impulsive and weak type, correctly in my opinion links up the first with maniacal-depressive psychosis and the second with schizophrenia.

"On the basis of comparatively little clinical experience, I shall venture to formulate the following suppositions of mine concerning human neuroses. Neurasthenia is a pathological form of the weak general type and average type in human beings. Hysteria is a product of the weak general type in association with the artistic type, and psychasthenia

¹ *Pavlov* : speech at the Neurological Congress, London, 1935.

(according to Pierre Janet's terminology) is the product of the weak general type in combination with the thinking type.

"In hysterical persons, general weakness naturally has a special effect on the second signalling system, which in the artistic type in any case yields pride of place to the first system, while in normally developed persons the second signalling system is the usual regulator of activity. Hence arises a chaotic character of the activity of the first signalling system and an emotional background in the form of pathological fantasies and impulsive emotionality with profound destruction of the general nervous equilibrium (sometimes paralysis, at others contractures or convulsive fits or lethargy), and in particular synthesis of personality.

"In psychasthenics the general weakness naturally applies to the basic foundation of the mutual relations between the organism and environment, viz. the first signalling system and emotional background. Hence arises absence of the sense of reality, a continual sensation of the emptiness of life, unsuitability for life, together with continual barren and distorted thinking in the form of obtrusive ideas and phobias. Such in general outline is my conception of the origin of neuroses and psychoses in connection with the general and particular types of human higher nervous activity.

"The experimental study of pathological changes in the basic processes of the nervous activity of animals makes possible a physiological understanding of the mechanism of neurotic and psychotic symptoms, both separately and as entering into the composition of definite pathological forms.

"Weakening, as also inertia, of strong excitatory processes leads to the predominance of the inhibitory process both in general and particularly in the form of sleep and the hypnotic state with its numerous phases of which the paradoxical and ultra-paradoxical phases are especially characteristic. In my opinion a very large number of pathological syndromes should be referred to this mechanism, *e.g.* narcolepsy, catalepsy, sense of mastery (according to Pierre Janet) or inversion (according to Kretschmer), catatonus, etc. The weakening of the excitatory process is attained either by overstrain or by collision with inhibitors. Under conditions which have not yet been fully elucidated in the laboratory, the mobility of the excitatory process may change into a pathological lability. This is the phenomenon which has long been known clinically under the name of excitatory weakness, consisting in extraordinary reactive sensitivity of the excitatory process and rapidly followed by exhaustion. Our positive conditioned stimulus gives a vigorous and extraordinary effect, but the positive effect is reduced to zero even during the normal period of stimulation; in the state of inhibition this phenomenon is sometimes termed explosiveness.

"My data, however, include also the opposite pathological alteration in the mobility of the excitatory process, *viz.* pathological inertia. The excitatory process obstinately persists although the conditions have long been applied that normally alter the excitatory process into an inhibitory one. The positive stimulus is not at all, or only slightly, subjected to inhibition by the succeeding inhibitory stimuli. In some cases this pathological state arises

as the result of a regular but continually growing intensity of the excitatory process; in other cases it arises from collisions with the inhibitory process. It is quite natural to refer the phenomena of stereotypy, fixed ideas, paranoia, etc., to this pathological inertia of the excitatory process. . . .

“There remains one more task, and not at all an easy one, viz. to determine more accurately when and under what precise conditions a particular pathological alteration of the basic nervous processes takes place.”

If we remember that contemporary psychoneurology, in spite of all its successes, is nevertheless inclined sometimes to pay heed to doctrines of life force, it will become clear to us what enormous significance for science attaches to Pavlov's latest researches, since these are absolutely opposed to any doctrine of the “soul” or “entelechy,” and consequently also to any vitalistic theory of mental diseases.

“Is it not clear,” Pavlov remarked in his speech at the Congress of Medicine in Madrid in 1903, “that contemporary vitalism, that is animism, confuses the different points of view of the scientist and of the philosopher? All the marvellous successes of the first have been founded on the investigation of objective facts and their comparisons, ignoring on principle the question of essence and final causes.”

“These attempts at a physiological explanation of psychical phenomena are almost irritating even to many persons who are capable of scientific thought,” remarked Pavlov in his *Latest Communications*, “and consequently these explanations are angrily dubbed ‘mechanistic’ with the intention of sharply emphasiz-

ing that they are altogether out of place, an absurdity, a confusion of subjective experience with mechanics.

“At the present time, of course, it is impossible to think of representing our psychical phenomena *mechanically*, in the literal sense of the word, just as it is impossible to do so in regard to all physiological and, in a lesser degree, chemical and in their entirety even physical phenomena. A genuine mechanical interpretation remains the ideal of the scientist, to which the investigation of all that exists, including ourselves, only slowly approximates, as it will continue to do for a long time yet. All modern natural science as a whole is only a long chain of *stages of approximation* to a mechanical explanation, stages that throughout their extent are united by the higher principles of causality, of determinism; there is no effect without a cause.”

Quoting these words in an article written on the occasion of Pavlov's death, A. Deborin remarks: “Pavlov appears here before us as a *mechanical materialist*. It is possible to join issue with what he calls the mechanical *ideal* of the scientific investigator, but this is not the point. What is important is Pavlov's endeavour to give a *materialist, i.e. physiological*, explanation of psychical phenomena.”

Pavlov considered that this was his chief task towards science and he fulfilled it to the end.

Chapter VIII

PAVLOV'S METHOD OF WORK : HIS SCHOOL

THE HISTORY OF PAVLOV'S LIFE IS THE HISTORY OF HIS WORKS

WE have now surveyed, if only in brief outline, the historical origin and development of Pavlov's method, and have attempted to characterize the chief stages in Pavlov's theory of higher nervous activity. It is very natural that the question should now be asked: Who was this man who succeeded in adding so much that is new to the concept of reflex action, a phenomenon which had occupied the attention of scientists from Descartes to Sechenov? Who was this man who, next to Darwin and Fabre, was able to introduce so much that is new in the theory of animal instincts?

Pavlov adopted all the best that could be given by the history of materialism, beginning from Democritus, while being able to avoid anthropomorphism in studying animal life, although historically anthropomorphism has been closely connected with mechanical materialism.

Pavlov did not diffuse his energies in fruitless attempts to discover the chemical nature of animal behaviour, although he was firmly convinced that the basis of higher nervous activity, as of all activity of the brain, lies in chemistry and physics.

Finally, during the last years of his life, Pavlov

enlisted for the solution of his purely physiological problems modern biology as represented by genetics, and modern clinical knowledge as personified by Pierre Janet and Kretschmer. At the same time, however, he avoided the dualism characteristic of modern psychiatrists in the West.

A brief description of the life of this exceptional man, of this scientist pre-eminent among scientists, is of great interest for everyone who values the development of contemporary natural science.

Externally, Pavlov's life was not marked by any great variety. Practically his whole life was passed in one city, Leningrad, and almost always under the same conditions of intense laboratory research. This fact, however, only causes the rich internal content of his life to stand out the more clearly, being as it was a life filled with wide scientific interests and important discoveries.

Pavlov was born in 1849. The so-called liberation of the Serfs took place when he was already a boy of 12, while the Russo-Turkish War of 1877 found him a fully-grown man who had just graduated from the Medical Academy. Superficially, therefore, it would appear as if Pavlov belonged to the last century. However, as a scientist and the founder of a new school in the physiology of the nervous system, Pavlov, like Planck and Einstein, personifies the highest aspirations and most valuable scientific achievements of twentieth-century science. We have mentioned that the first book on physiology that Pavlov read while still at school was G. H. Lewes' *Practical Physiology*, his copy of which he kept in his library throughout his life.

Pavlov received his first education at the Church

School in Ryasan. He was very early in life seized with a desire to learn, and while still at school would spend hours studying in the library copies of the journal *Sovremennik* (*Contemporary*), which contained the critical essays of Pisarev, whose views he came to value very highly. Like Sechenov, he was attracted to the subject of medicine by the exactness of its formulæ and its materialist world-outlook.

The young Pavlov became a student of St. Petersburg University and afterwards of the Medical Academy. His teachers were, first of all, the Russian physiologist Tsion, and later also the German scientist K. Ludwig and the clinician S. P. Botkin. His older friends were Mendeleyev, Sechenov and Schiff, whom he attempted to imitate in his work, at least during the early days.

Fundamentally, however, Pavlov's nature was one marked by great originality. His student's thesis of 1878 on the ligature of the bile duct already bears the impress of his outstanding talent. This talent manifested itself especially strongly in his dissertation, entitled *The Centrifugal Cardiac Nerves*. Thanks to this work of his, science was enriched by the concept of nerves which regulate the activity of the heart, altering the *force* but not the *frequency* of the contractions of the cardiac muscle. This discovery ranks as the first in the theory of the so-called *trophic* innervation of organs which is now recognized as being of great significance.

The further development of Pavlov's scientific career was as follows: His first experiments were carried out in Botkin's little laboratory located in an outhouse attached to the latter's clinic in the Vyborg district. His financial resources at this time were

very small and he had to practise great economy both in his daily life and scientific expenditure. Moreover, he was often compelled to take the laboratory animals (dogs) into his own lodgings in order to look after them.

In 1884 Pavlov succeeded at last in obtaining a fellowship enabling him to travel. He spent the two years of his stay abroad in establishing close scientific relations with Ludwig and Heidenhain. On his return he began his first attempts at making fistulæ of the ducts of the digestive glands so as to obtain their secretion in a pure form, and he completed these researches by a number of classical operations on various parts of the alimentary tract.

In a small building on Aptekarsky Island belonging to the newly-founded Institute of Experimental Medicine, Pavlov organized the first clinic and operating theatre in the world for animals that was organized on the lines of "human" surgery. Thanks to careful attention to aseptic conditions, his animals almost invariably survived the operations. Under the skilled hands of Pavlov, the secrets of the dog's organism were rapidly laid bare; by his fistula method the mystery of digestion was gradually cleared up and its chemical character demonstrated, as also the nervous mechanism of the highly complex digestive processes.

In 1890 Pavlov was appointed Professor of the Military Medical Academy, first in the Chair of Pharmacology and later of Physiology. In this capacity, for thirty-four years consecutively he continued his fertile work both as an experimenter and as a gifted teacher. Nevertheless, for some time Pavlov remained little known outside a restricted academic

circle. In 1897, however, Pavlov collected the results of his experiments on digestion and published them in a small but brilliantly written book in which his results are expounded almost in a popular manner but with a remarkable depth of content. All who read it were able to convince themselves of the birth of a new chapter in science of enormous significance. Pavlov's work caused a sudden and marked change in all our ordinary conceptions of digestion. Throughout the world, physicians were entranced with these *Lectures on the Work of the Digestive Glands*, and there is not a single clinic or hospital in the world where the results of Pavlov's researches performed on animals have not been applied in treating diseases of the stomach and intestines in man.

Pavlov received thousands of letters and books which he had to answer and review; numerous young investigators from abroad came to study under him. He was awarded a Nobel prize. Many scientific societies, including the Russian Academy of Sciences (1906), elected him a member.

But Pavlov was not in the least content to rest on his laurels. He prepared once more to astonish the scientific world by the novelty and freshness of his discoveries. In 1903, at the International Congress of Medicine in Madrid, he delivered his remarkable report on the experimental investigation of the psychical activity of animals.

In studying psychical salivary secretion and conditioned reflexes, as we have already seen, he in fact studied the life of the brain itself, the dynamics of higher nervous activity. Pavlov then made his proposal that zoo-psychologists should begin their studies by an investigation of these very simple mani-

festations of individual adaptative activity so as gradually to approach the problems of its more complex manifestations in voluntary and conscious acts. Unfortunately, the zoo-psychologists in Europe did not accept the hand of the physiologist held out to them; instead of the prosaic task of counting drops of saliva, the majority of them preferred as before to concentrate on intuitions and guesses as to the internal world of animals, relying on the data of self-observation.

It was then that Pavlov's exceptional polemical talent began to be demonstrated in all its extent and power. Pavlov made use of every session, every report and lecture—whether among groups of British or other scientists, or whether among young Russian students; with a liberal hand he scattered broadcast ever new facts from the extensive harvest yearly reaped by him in the laboratory. Not less than thirty of his oral reports to scientific bodies (Pavlov in general was not especially fond of writing) were devoted to propagating his new system of views on the activity of the cerebral cortex which was then being investigated by him from all aspects. And it is no wonder that he put forward his views so insistently, for it was not a question of describing some new apparatus or particular method of research but of producing a complete revolution in the minds of his scientific contemporaries.

The World War considerably hampered the development of Pavlov's work, but on the other hand it was just during these years that he matured his theories of sleep and of the types of higher nervous activity, theories that have exercised very great influence on the further course of his experiments.

At the beginning of 1917, being at the time confined to bed as a result of fracturing his thigh, Pavlov began to write a book in which he made it his aim to sum up all the data of his experiments and to prove that the brain which has created natural science has become in fact an object of study of natural science. This book, entitled *Lectures on the Work of the Cerebral Hemispheres*, only saw the light some nine years later, in 1926, since Pavlov considered it necessary that each of his works should be set aside for a time for consideration before being published.

Approximately on his seventy-fifth birthday a special decree was issued signed by Lenin, which recognized Pavlov's exceptional services to science, and instructed the State Publishing House to publish the results of his twenty years of work in the form of a collection of reports and speeches. This was the origin of Pavlov's famous book, translated into English under the title of *Lectures on Conditioned Reflexes*, a book which characterizes the gradual development of Pavlov's ideas.

This book has been translated into almost all foreign languages. This is not new; what is new is that the book is now not only to be found in special libraries but is read and studied by teachers and lawyers. It has been the source of fierce disputes in literary and other circles. It has been hotly criticized, but in combating the idealist tendencies of certain modern scientists, recourse is always had to Pavlov's theory of conditioned reflexes as an effective weapon familiar to friends and foes.

During the last period of his life, Pavlov was at the head of three enormous laboratories (the third of

them being at the Soviet farm "Koltushy"). Altogether more than fifty scientific collaborators worked under him. Every day a multitude of animals came under his attentive eye, from white mice to anthropoid apes. These laboratories may be looked upon as an enormous factory of diverse reflexes, an incubator of new scientific theories. All this tremendous scientific activity was directed by Pavlov himself, who maintained a spirit of friendly emulation among his collaborators, encouraged the backward, and himself guided the training of the young research students.

PAVLOV'S CREATIVE WORK: HIS INDEFATIGABLE ACTIVITY

There are discoveries in science which are born unnoticed in the heart of the laboratory and which seem at the outset very remote from practical life, although sometimes it is just these discoveries that prove to be responsible for the refutation of old views and the birth of a new outlook on the world. Years pass, the sphere of application of a scientific discovery that at the beginning was of purely theoretical interest gradually widens, and finally the day comes when masses of people become interested in the successes of science and snatch the discovery of the theoretician from the obscure retreat where it has passed its first years, so that it is brought out into the open and subjected to the broad appraisal of practical life. It happened so with the discoveries of Charles Darwin; it happened so also with Pavlov's discoveries in regard to conditioned reflexes.

The objective method of studying higher nervous

activity was gradually brought into being during a whole decade from 1902. However, the hopes, doubts and successes of the group of scientists who, under the leadership of Pavlov, devoted themselves to the detailed study of cerebral activity in dogs, remained for a number of years prior to the Russian Revolution little known except to a narrow circle of specialists among physiologists and physicians.

In looking back over the path traversed by Pavlov and his school, we realize that the isolation of the first part of his path made it possible for the founder of the theory of conditioned reflexes to lay a firm foundation for his profound investigation into the functions of the brain, a foundation such as no other physiologist or psychologist working on the subject of nervous activity had been able to create.

In our opinion, another source of the tremendous power of Pavlov's theory lies in the fact that it is as it were cast from a single mould, that it represents the product of many years of activity of a single indefatigable mind guiding and uniting the efforts of a number of persons sincerely devoted to the search for truth.

My first meeting with Pavlov was at his introductory lecture to the students of the Military Medical Academy in September 1911 (see *Frontispiece*). This lecture was devoted to general academic questions. In a striking and easily understandable way, Pavlov expounded the qualities that he considered should be possessed by a medical student, as a future physician and therefore an "engineer of the human organism," which his efforts have to restore to its normal activity. He spoke of the serious responsibility of the physician, but he did not introduce

the slightest note of doubt as to the possibility of the help that could be rendered by the physician. He said that in choosing to be an engineer one must necessarily study the material to be dealt with, in this case the suffering human body. None of the other professors had spoken to us in this way. On the contrary, the fashionable view at that time was that of Veresayev, who openly declared that he regarded medicine as powerless.

That very first acquaintance with Pavlov inspired in many of us such a desire to take part in the investigation of living matter, such respect for the men who were occupied in finding out the obscure secrets of health and disease, that even a quarter of a century later his very words remained in our memory. Such was the power of this man, the compelling nature of his speaking and the depth of his thought.

Our course of instruction followed the regular lines. Pavlov's lectures in the Academy, occurring on Thursdays (one hour) and on Fridays and Saturdays (two hours), always made a profound impression on us. In his lecture hall in the Vyborg district, a tremendous physiological drama was unfolded before our eyes, a great historical chronicle of which the authors were Claude-Bernard, Ludwig, Heidenhain, Schiff, Tsion, Brown-Sequard, Sechenov and other classical physiologists, and the unknown actors were the ordinary laboratory animals which B. P. Babkin, N. P. Tikhomirov, and later L. A. Orbeli and G. V. Volborth prepared for the demonstration experiments in a large room adjacent to the lecture hall.

The chief and untiring stage-manager of the drama was, of course, Pavlov himself. He encouraged,

urged on and kept in awe all those on whom the success of the experiments depended. Moreover, he demanded that the experimental table mounted on wheels with the ready-prepared experiment should appear before the eyes of his hearers at the exact moment required. "As soon as it is ready bring it in," was always his last instruction on leaving the preparation room and coming into the lecture hall.

Behind the scenes there were always numbers of young physicians preparing their dissertations, who enthusiastically worked on special subjects. In the lecture hall, however, we students were not merely silent spectators. We were fully-privileged participants in the drama that was being unfolded; from the very first lecture we received from Pavlov the inestimable right of interrupting him literally in the middle of a word, if we wished to put a question on something that was not clear in what he had just said. Naturally we valued this right very highly although we did not abuse it. It was an excellent teaching device of Pavlov's; it increased our attention and responsibility tenfold, and at the same time trained our capacity to realize when we did not understand. And it was just this that formed an important element in Pavlov's teaching. In his lectures and in his printed utterances, Pavlov repeatedly emphasized the importance of mutual trust between those taking part in any work, and declared in all seriousness that his discussions with his students had more than once inspired him to make new investigations.

The intervals in the exposition were devoted to answering questions and sometimes even to repeating or varying an experiment, of course without interfering with the harmonious development of the

course of instruction. This depended on the fact that all the lectures had been previously rehearsed down to the smallest details during the many preceding years of Pavlov's activity. An interesting detail is that Pavlov's punctuality was so great, and so heightened by practice, that he always entered the lecture hall not on the minute but on the second. His last words, summing up the whole lecture, always coincided accurately with the bell indicating the end of the hour.

Our impatience to take part in this new world of thought and labour grew continually. Many of us, after hearing the whole of his annual course of lectures, and enthusiastic over his ideas, followed him through the glass door to the laboratory, which was filled with improvised chambers for work on conditioned reflexes.

Pavlov suggested to me that I should make experiments on conditioned reflexes in the dog, in which the stimuli were to be the previously mentioned screens. These Pavlov at once proposed should be made on the spot by colouring paper with Indian ink to various degrees of intensity, while awaiting the arrival of the necessary illumination screens from Ostwald in Germany. He himself demonstrated how to make such screens from Bristol board. A special place was assigned for my work in a corner of the photographic room, which had the advantage of already possessing the degree of obscurity necessary for the experiments.

Here we see another feature characteristic of Pavlov, along with his attentiveness to young research workers, viz. his ability to work with the minimum of scientific equipment. A metronome,

a feeding receptacle and a piece of Mendelejev's wax were all the equipment of the experimenter at that time, not counting the skilful hands of Pavlov himself, who performed an operation with the precision of a microtome and the speed of a cinematograph.

Thanks to Pavlov's organizing talent, there developed from these simple "elements" the tremendous technical resources of the modern science of behaviour; there arose the mammoth organization of the Physiological Section of the Institute of Experimental Medicine.

During our student days we of course all read Pavlov's words contained in the Preface to his *Lectures on the Work of the Digestive Glands*, where he describes his attitude to all scientific collaborators:

"Before the laboratory investigator there is unfolded as it were a single idea that becomes increasingly embodied in solidly based and harmoniously connected experiments. . . . And this view is a cause common to all, a *matter of the general atmosphere of the laboratory, to which each contributes something and which as a whole is respired by all.*" (Our italics, Y. F.)

Although the fame of Pavlov's laboratory and reports of the friendly co-operation prevailing in his team of workers had reached us earlier, nevertheless when the former student became himself a scientific worker, even if far from a perfect one, he experienced for himself this beneficent *atmosphere*, this remarkable "climate" in Pavlov's laboratory, in which scientific discoveries of enormous significance were ripening almost before our eyes, in which the heavy labour of research seemed the lightest and most

pleasurable form of human activity, and in which every minute of rest was utilized for conversation with the teacher so as to become acquainted with his views on life and scientific work.

The scene which we are now going to describe took place five years later, in 1919, when some of Pavlov's collaborators who had been temporarily divorced from the laboratory by being called to the War returned to the Institute of Experimental Medicine. It was a difficult period. The food crisis hindered the normal work of the scientific institutions in Leningrad. Valuable animals were perishing one after the other. It was necessary to give the experimental dogs a share of one's own meagre rations, and even this hardly helped. It was necessary to supplement this food supply, and so the laboratory workers used to set out on their own account to visit mills and warehouses in the city in order to obtain extra food.

But Pavlov did not lose heart. When the electric light failed and even candles were unobtainable he operated by the light from splinters of wood ; when the tram service stopped he came to the laboratory on a bicycle, although he had not fully recovered from a serious thigh fracture.

Most striking of all during this year of difficult food conditions was the way in which Pavlov assiduously cultivated a small plot of land, granted him by the Institute, so as to ensure an adequate supply of vegetables during the winter. He always insisted on the importance of everyone devoting some time to manual labour, and in this case he had in addition the important stimulus of securing food.

This year, in which Pavlov made his first visits to the clinic for observation on the previously described case of twenty years' sleep, was remarkable for the development of many new ideas. Even the starvation of the experimental animals was utilized for revealing new pathological forms of higher nervous activity, in which the conditioned reflexes gradually lost their force while inhibition, on the other hand, began to have a positive effect (the so-called ultra-paradoxical phase).

In this year I received the honour of cultivating a piece of land adjoining that on which Pavlov had spent so much labour. Pavlov dug and weeded the beds with as much systematic care and concentration as if he were performing some highly important experiment. In fact, he never forgot to make observations on himself during the whole time that he worked.

While partaking of the traditional tea in the laboratory, Pavlov declared, laying especial emphasis on his words which he wanted us to remember: "I cannot even compare the great satisfaction derived from manual labour with that obtained through mental effort, although I live all the time by the latter. This is obviously dependent on the fact that my grandfather himself ploughed the soil. The vocation of scientific work does not exclude the necessity for performing manual labour and sometimes even of living by its results." And he pointed to his bicycle with the basket of vegetables attached to the saddle.

Unfortunately, it is not everyone who could boast of such strength of character and, under the conditions of feverish work on the newly-discovered

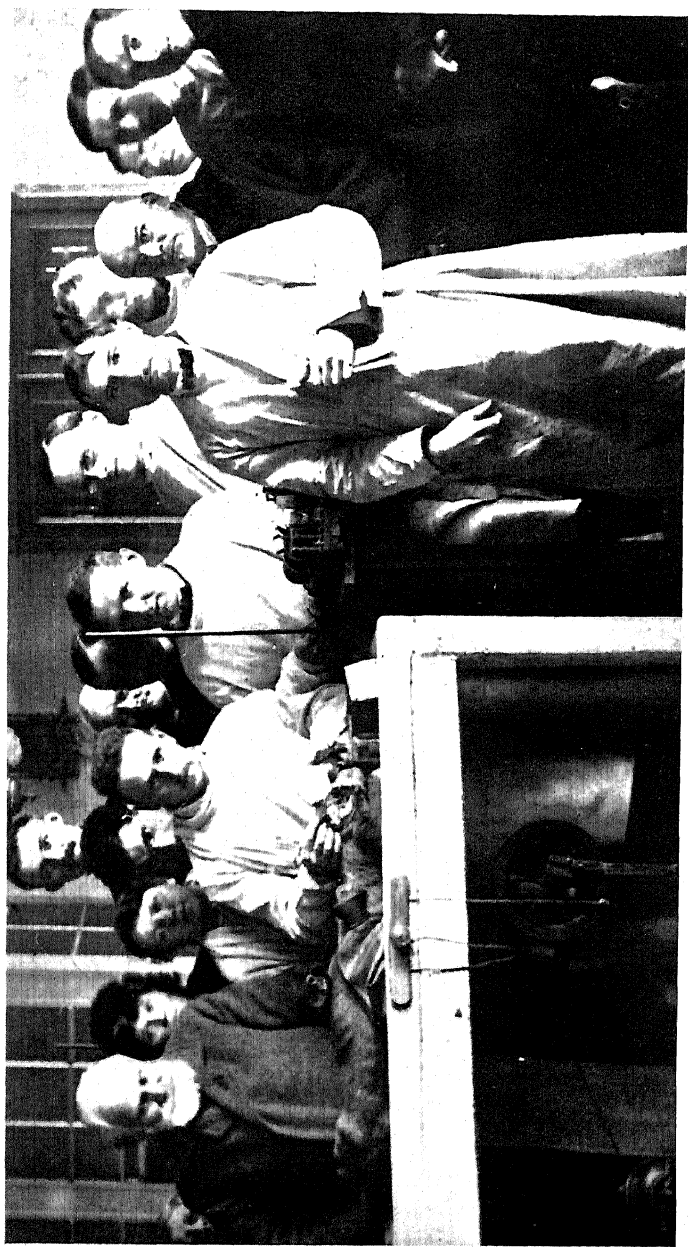


FIG. 23. I. P. Pavlov lecturing in 1924

complexes, at least a third of my particular vegetable plot remained uncultivated. Pavlov never ceased to reproach me for this right up to the time when I left to serve as a doctor at the front during the Civil War. On my return to the laboratory the necessity for growing our own vegetables had already passed.

A new life was being built up, Leningrad's wounds were healing. Pavlov's laboratory in the Medical Academy, where I was his assistant, was filled with a new generation of students who loved and respected Pavlov as a marvellous teacher (Fig. 23). These years, a period of the reconstruction of national economy in the Soviet Union, brought an entirely new influence into the internal life of the laboratory and directed Pavlov's mind to entirely new objects. It was during these years that the idea of building "Koltushy" took shape, and that Pavlov began to interest himself in problems of internal secretion, heredity and the study of old age, as well as the clinical treatment and prevention of diseases of the nervous system.

The tremendous apparatus brought into being by the highest Soviet authority for assisting Pavlov's ever-widening scientific interests, the incessant flow of excursions from factories and educational institutions, the enormous correspondence from physicians, teachers, agricultural engineers, etc., daily arriving at Pavlov's address—all this had its part in the extraordinary new flourishing of his creative activity.

In these years, indeed, the laboratory resembled a tremendous blast furnace in which the raw material of facts was smelted into a stream of brilliant hypotheses, and the latter, after they had been allowed

to cool and had undergone persistent shaping at Pavlov's hands, gradually acquired the firm outlines of scientific theories. The Twelfth and Thirteenth International Physiological Congress, as well as the Psychological and Neurological Congress, greeted Pavlov's appearance on the platform with a storm of applause. They served as world laboratories in which the high quality of Pavlov's theories was tested and given the stamp of general approval.

Pavlov's indefatigable activity continued at its previous high level right up to the end of his life. His joy in life and his deep sincerity, qualities that pervaded all his lectures, found expression for the last time in his address as President of the Fifteenth International Physiological Congress, meeting for the first time in the Soviet Union.

"Ours is a young physiology," Pavlov declared in his introductory statement addressed to the scientists of the whole world who had greeted him as the doyen and most eminent of physiologists, the teacher of a whole generation of scientists.

What were Pavlov's thoughts at the opening of this Congress, where he had an audience ten times greater than that of his previous lectures? He spoke of the special influence exerted by such gatherings of active scientific workers on the new generation, on young scientists:

"The strength of this influence I know from my own experience, from my youthful years," said Pavlov. "Our government is granting extraordinarily large sums for scientific work and is attracting a mass of young workers to science, and the spectacle of world scientific research represented here is bound

to have a tremendous stimulating effect on our youth."

Thus we see that thought for youth and concern for them never deserted Pavlov at any time during his life. It was solely thanks to this precious quality that Pavlov could create as he did such a powerful scientific school.

THE CAUSES OF THE GROWTH OF PAVLOV'S SCHOOL

When one speaks of a scientific school, one implies by the term not merely a certain group of investigators engaged in research in some particular sphere of science under the leadership of a teacher who is the head of the school. The term refers also to a definite body of views and ideas, to a whole complex of special methods of investigation. The latter are transmitted as a sort of scientific tradition, being sometimes handed down through a number of generations of scientific workers.

During the first period of Pavlov's fruitful scientific activity, prior to 1904, he trained with great success some eighty new scientific workers engaged in research on the complex problems of digestion. After embarking on the study of higher nervous activity, there passed through his laboratory some 200 scientific collaborators, not counting those who came from abroad to study under him.

If we assume that each of these pupils of his has in turn trained at least two scientific workers (and in most cases the number will really be much greater), we obtain a kind of pyramid in which the work of Pavlov himself at the apex passes down into the work of many hundreds of highly skilled investigators,

each of whom continues to carry out research in his field of modern physiology.

For the vast majority of his pupils, Pavlov's scientific authority is unquestioned. What is it that holds together this tremendous pyramid, what is the driving force of this remarkable scientific machine which has now been in operation for more than half a century? Besides the high personal qualities of the leader himself, the inspiration and driving force lies in an exceptional system of organization of scientific research work.

Pavlov's system of preparing scientific cadres came into being gradually; it has nowhere been analysed, nor does any written description of it exist. Yet there are many scientific and technical workers, as well as teachers in higher educational institutions, who have had occasion to become acquainted with it in detail. In his lecture of April 23, 1921, Pavlov gave a first sketch of the "basic qualities of mind" indispensable to a scientist.

The first quality on which he laid stress is that of stubborn *concentration* of thought, the capacity "to think unceasingly about a particular subject, to go to bed with it and to get up with it." In his last letter to Soviet youth, Pavlov termed this quality the *passion for science*.

Secondly, there is required unusual *concreteness* of thought, the ability to envisage reality in all its diversity and all its contradictions.

Pavlov puts in the third place exceptional *facility in constructing scientific hypotheses*, the capacity "to get behind the facts," as he used to say.

Fourthly, there must be *impartiality of mind*; if only a single fact conflicts with a hypothesis, the

latter must be mercilessly rejected—so Pavlov taught his students. These two qualities, freedom in constructing hypotheses and impartiality, are not at all in contradiction to one another. Pavlov often fired the scientific imagination of his hearers only at the next moment to apply the severe test of facts to the scientific “vision.”

His fifth requirement was readiness to *test*. Pavlov was not afraid of repetition, and even welcomed it. In his course were included experiments which had been repeated by him each year for half a century. And yet each time he approached them with some anxiety—“Perhaps it will not succeed this time,” he used to think to himself. But the experiment was always successful.

The sixth place is occupied by *attention to detail*. For Pavlov, when he was conducting an experiment, there was nothing of secondary importance in the circumstances of behaviour. Everything received his intense attention. Seventhly, and finally, we have the requirements of *modesty* and *simplicity*. “Never think that you know everything. Always have the courage to say to yourself, I am ignorant.” The more complicated the theory to be expounded, the more precise and clear was Pavlov’s language.

Pavlov did not like persons who made a display of wisdom. “Truth,” he said, “is always simple. Men of genius are simple and clear.” These words express in essence the whole biography of Pavlov. We might note that Pavlov himself considered all the above qualities to be to a very large extent a matter of “training,” and attainable by anyone who was not afraid to learn and to work.

At the end of his life, Pavlov once more summed

up these principles in a letter addressed to Soviet youth. This letter, which was published posthumously, is as follows:

“What is it that I would wish the young men and women of my country who have dedicated themselves to science?

“First of all—consistency. Of this very important condition of fruitful scientific work I can never speak without emotion. Consistency, consistency and again consistency. From the very beginning of your work, train yourself to strict consistency in the acquirement of knowledge.

“Learn the ABC of science before you attempt to scale its peaks. Never embark on what comes after without having mastered what goes before. Never try to cover up the gaps in your knowledge, even by the boldest guesses and hypotheses. Such a bubble may delight your eye by its play of colours, but it will inevitably burst and you will be left with nothing but confusion.

“Train yourself to reserve and patience. Learn to do the heavy work that science involves. Study, compare, accumulate facts. Be the wing of a bird never so perfect, it would never bear her aloft without the support of the air. Facts are the scientist's air, without which he would never be able to fly. Without facts, your theories are labour in vain.

“But in studying, experimenting and observing—try not to remain at the surface of the facts. Do not turn yourself into a museum custodian of facts. Try to penetrate into the secret of their origin. Steadfastly seek the laws that govern them.

“The second thing is—modesty. Never think that you already know everything. And however high

the esteem in which you are held, always have the courage to say to yourself: 'I am ignorant.'

"Do not allow pride to take possession of you. It will cause you to be obstinate when you should be conciliatory. It will cause you to reject useful advice and friendly help. It will prevent you from taking an objective view.

"In the collective which I have to guide, everything depends on the atmosphere. We are all harnessed to a common cause and each of us helps it forward to the extent of his strength and possibility. With us it is often impossible to distinguish what is 'mine' and what is 'yours.' But our common cause only gains thereby.

"The third thing is—passion. Remember that science demands a man's whole life. And even if you had two lives, it would not be enough. Science demands from man great intensity and deep passion. Be passionate in your work and searchings.

"Our fatherland is opening wide prospects before scientists and—it must be owned—science is being fostered in our country with the utmost lavishness.

"What should I say of the position of the young scientist in our country? Is not everything quite clear here? Much is given him, but much is asked of him. For youth, as for us, it is a matter of honour to justify the great trust that our fatherland puts in science."

PAVLOV'S FAMOUS "WEDNESDAYS"

Pavlov's "Wednesdays" began approximately in 1927. At these gatherings of his collaborators there were as a general rule no fixed reports, except for a short introductory statement by Pavlov himself,

There were no tables or theses, which are sometimes employed only to dull the keenness of the hearer's perception. All the material had been previously prepared during conversations with the students; it had also been discussed by Pavlov in the laboratory during the course of work and during his excursions on foot among Leningrad's innumerable bridges and embankments.

In this way the themes matured for the discussions that took place in the "Wednesday" held at the Physiological Institute of the Academy of Sciences on the Tuchkov Embankment.

Any fact acquired in the laboratory by one of the scientific workers was discussed by Pavlov during several days with different groups of his collaborators. This was followed by many hours of "incessant" thinking on the part of the leader of the school himself, and then at the next "Wednesday" it was found that in the discussion the new fact was put in its place among those previously obtained in the laboratory.

The "Wednesday" itself existed principally in order that all who desired could take part in bombarding the new fact from all points of view. Only one thing was strictly forbidden, to rely on one's many years of personal experience in the laboratory. In the discussion everything was regarded as fundamentally disputable, not for the sake of argument, but for the sake of shortening the period of scientific searching, that can be so torturing if carried out in solitude.

Pavlov himself audaciously spurred on his hearers in discussion, endeavouring to obtain the maximum possible number of objections, in order very often to

give a brilliant refutation of them. In this way he sharpened the tried weapon of his analysis and taught his students to handle critically facts and especially theories. In these discussions all were on an equal footing; they were open to all who genuinely desired to help by working and thinking on the subject of the physiology of the cerebral hemispheres.

Very characteristic was Pavlov's manner of giving out a scientific subject for a dissertation or regular scientific work after preliminary experiments had been concluded. In this respect, Pavlov, as the organizer of the scientific interest in the work of the laboratory and as responsible for planning its separate parts, had no equal.

He made a special ceremony of the actual moment of formulating and giving out the theme for work. He began the conversation with a history of the problem, passing on to the fact that this subject was in some ways a decisive one, that it was difficult but interesting, etc. Sometimes he divided one subject between two or more collaborators, assigning to each of them a special type of experimental animal and afterwards organizing competition in the depth and high quality of the work done on the theme.

Thus, Pavlov recognized division of labour even in such a high form of labour as that of the experimental biologist. In this respect he was the inaugurator of the American system of organization of scientific institutes. The only thing that he could not tolerate was stereotyped thinking. He required from the collaborators in his experiments a special ability to alter their work in the course of its progress, demanding flexibility and practical adaptability in

thinking, as also attention to so-called trifles and exceptions.

In general, Pavlov refused to recognize negative results of an experiment. Searching for the causes of an apparent failure, he drew precisely from such "failures" material for new conclusions and new subjects for experiment.

He was fond also of giving introductory tasks which sometimes caused a radical change in the direction of the whole work. The harmonious character of the research, however, did not suffer; the course of the experiment which had been interrupted for a time was renewed later, and the basic aim always attained, although perhaps by other means.

All those corrections and observations that sometimes destroyed the whole standpoint of the author, were imparted by Pavlov in such persuasive form that no one was dissatisfied and every participant felt that he or she was a necessary part of Pavlov's great research mechanism.

In solving especially difficult problems and those important from the point of view of method, Pavlov sometimes had recourse to a special kind of scientific competition. He set all his colleagues the task of thinking about them for a definite period and then collected all the solutions, which were subsequently discussed at the "Wednesday."

An interesting point is the old practice established by him in the laboratory of levying fines for using terms from another science, particularly psychology, in order to avoid confusion and muddled thinking. It should be added that with the strengthening of Pavlov's own school and its physiological termi-

nology, which removed the danger of confusion of language, this system of fines was abolished. However, in permitting during the recent period the use of terms such as "forgetfulness," "doubt," and "disillusionment" in application to the dog, and in employing sometimes human phraseology in reference to animals, Pavlov always demanded that each of these conceptions should have an accurate physiological interpretation.

In the internal organization of scientific work, Pavlov maintained the principle of the open door; he did not recognize any laboratory secrets. He himself was the first to announce the success or defeat of every effort of himself and his collaborators.

Pavlov attached enormous importance to the circumstances and *technique* of research. The assistants in the laboratory, especially those concerned with operations, were for him not merely laboratory assistants but valued helpers in the general work.

Finally, a few words must be said of his methods of *testing the fulfilment* of work assigned and appraising the scientific results attained. The latter task was the most complicated of all. The fact is that work with animals by the method of conditioned reflexes is very laborious; as mentioned above, some experiments were carried on for years. Some animals were under observation for seven years or more and continued to provide new data. It is clear that in passing from one stage to another it was necessary to come to a stop somewhere. Pavlov was accustomed to regard a piece of work as completed when, besides answering the question asked, it provided material for two or three new

pieces of research, which he sometimes entrusted to the same person but sometimes handed over to others.

When a piece of work had been completed, Pavlov put it aside for a year or two to "mature," and only after this did he allow it to be printed. Consequently the percentage of unsuccessful work in his laboratory was insignificantly small. A piece of work which had been carried out decades before remained valid as regards the basic results obtained and the general picture presented in so far as the facts are concerned, even if the view taken of them might become essentially different later on owing to new technique and a new system of ideas. Pavlov always attempted to deal only with factual data acquired *at first hand*.

Pavlov carefully corrected his own work and that of his colleagues when in final written form, down to the last comma.

Such was Pavlov's school, such was the general style of his work.

PAVLOV AT HOME

The following is a description of Pavlov's working day given by the well-known writer, E. Lagansky.¹ In order to note the following details, Lagansky spent several weeks in studying Pavlov's routine of work.

"Pavlov's working day began early, at 7.30 a.m. Only during this last year has he allowed himself an additional half-hour of sleep as a meagre tribute

¹ These data are taken from an article, written while Pavlov was still alive, which has appeared in a number of non-Russian journals. We reproduce this article here in an abbreviated form.

to his age. His time-table was always as accurately fixed as that of a railway train. Exactly at 8 o'clock he drank his morning tea, together with milk, bread and butter. He invariably spread the butter with his left hand. All the same, he was not left-handed; he could use either hand equally well. He operated with the left hand and also used it in playing skittles.

"He passed the time until 8.30 in absolute quiet. For this purpose he was accustomed to seat himself in a comfortable arm-chair and enjoy the sight of his collection of pictures, of which he had accumulated about a hundred during his life, all by Russian artists.

"After taking his rest among his pictures, Pavlov went into his study. Here he busied himself with scientific work until 9.30, at which time he left for the Institute of Experimental Medicine. This was on Tuesdays and Saturdays. On Fridays he set out at 9.30 for the Koltushy Biological Station and spent the whole day there until 5.30. On other days, Pavlov worked at home in the mornings somewhat longer, until 9.50. He maintained that these morning hours were the best and most productive times for work.

"Pavlov always went on foot to the Physiological Institute of the Academy of Sciences, which he visited twice a week, and also to the neurological and psychiatric clinics of the Institute of Experimental Medicine. Pavlov was never late.

"From the Physiological Institute, Pavlov would walk back briskly in order to take his lunch. This was exactly at 12.30, and to it he assigned half an hour from his crowded time-table, including some time spent on his favourite game of patience. The

game of patience invariably occupied some part of his hours of rest at home. It formed the finishing touch to lunch, dinner and supper.

"After lunch, Pavlov would spend the whole of the next hour lying down and examining with inexhaustible delight the minutest details of his familiar collection of pictures, or sometimes he would listen to favourite airs on the gramophone. Pavlov was a great lover of music. Many singers of the Leningrad State Opera House knew this passion of his, and sometimes on rest days they would visit Pavlov in order to give the great savant the pleasure of hearing them sing. Pavlov himself never went to the theatre.

"In literature, he loved the classics, being especially fond of Goethe and Shakespeare. He always regretted that he had so little time for reading, apart from his summer holiday.

"The time from 2 to 6 in the afternoon, *i.e.* before dinner, Pavlov spent in various ways on different days, either in the Physiological Institute, or in Koltushy, or in the clinic, etc.

"Dinner was accompanied by as long a game of patience as time allowed.

"Pavlov rested until 9 p.m. At 9.30 he sat down to his evening tea and at 10 p.m. went to his study, where he worked until 1.30 a.m."

KOLTUSHY—A SOVIET DOWN

Koltushy, the estate named after Pavlov, is a new seat of Soviet Physiology, a unique kind of laboratory. Here there has been constructed a new type of scientific institution in which a rest home

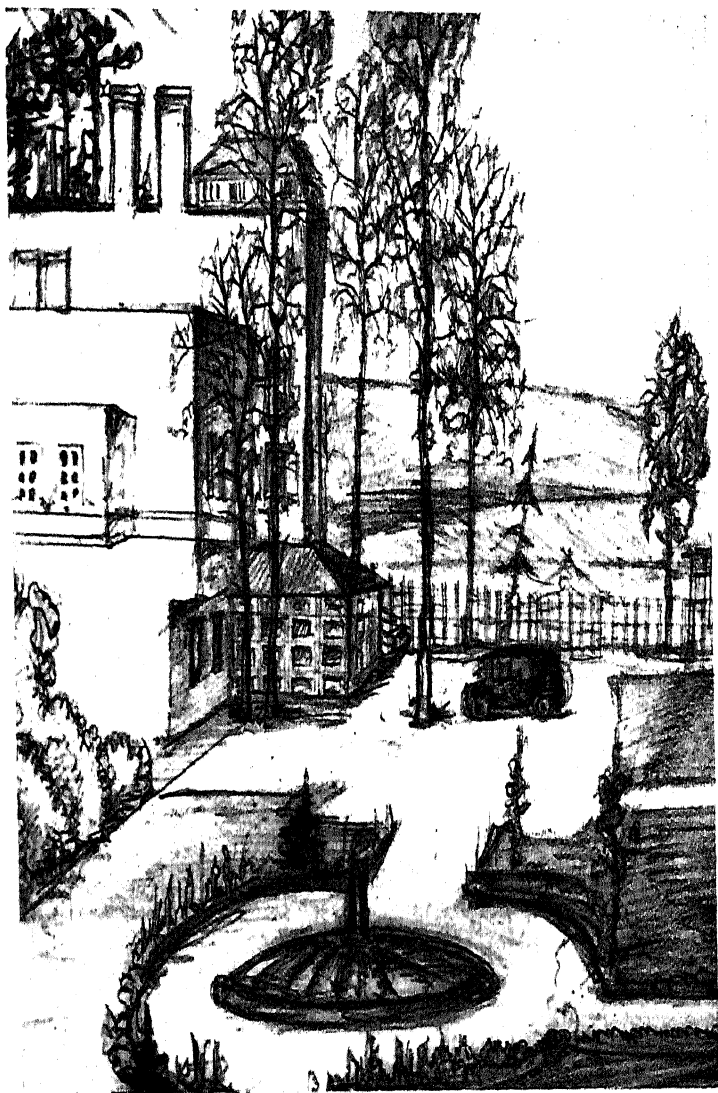


FIG. 24. The Koltushy biological station (now Pavlovo). General view from the balcony of the home built for Pavlov (pencil sketch by the author)

for scientific workers is combined with intense scientific work on the study of higher nervous activity in animals (Fig. 24). At Koltushy is to be found the concentrated application of the most advanced laboratory technique. Here a special township has been built for the laboratory animals, mainly dogs, of which there are several hundreds.

Each of the animals has a separate place to live in, there is a splendidly equipped, mechanized kitchen, a hospital, a common exercising hall and even a maternity centre for the bitches.

The two chimpanzees, presented to Pavlov by Professor S. Voronov, also have their own building, which is fully equipped for experiments.

All the latest technical improvements, such as those mentioned earlier, have been installed here to make the work of the experimenter more convenient and productive. Complete mechanization of the experiments with animals is an indispensable condition for the new and extremely precise work of Pavlov and his school. Only by taking proper account of all data in relation to feeding, maintenance and general regimen of the animals is it possible to count on obtaining the necessary exact information on the comparative physiology of the brain and higher nervous activity.

Three bronze busts have been set up on the green lawn laid down by Pavlov's own hands at the side of the road. One of these busts is of Mendel, the discoverer of the famous laws of heredity. The other two are of Descartes and Sechenov, representing the starting-point and later development of classical knowledge of reflexes.

An obvious lack is a bust of Charles Darwin.

But the manner of work of this remarkable investigator makes itself felt at every step. In 1842, Darwin settled down to the solitude of his property, at Down, near London, where he spent his days observing the growth of plants and summarizing his conclusions by writing such great works as *Insectivorous Plants*, *The Expression of the Emotions*, *The Descent of Man*, etc.

Koltushy is essentially a new, Soviet Down. The difference, however, between the two is very great, as great as is the difference between Darwin and Pavlov, these creators of two of the great scientific theories of the nineteenth and twentieth centuries. Moreover, economics, technique and social conditions have all altered, erecting a boundary between the two epochs, the Darwinian and the modern.

It is well known that Darwin lived a hermit-like life in his retreat at Down. Although he was fond of society, he did not allow himself to meet anyone. "Few people have managed to lead such a solitary life as I have," he writes in his autobiography.

Pavlov, however, through the building of the Koltushy laboratory station and through his numerous visitors, kept in touch with hundreds of diverse activities. Like a high voltage conductor he transmitted his remarkable energy to his surroundings.

The Soviet State has expended exceptional attention on the newly-constructed laboratory station.

Pavlov took great pains not to waste a moment of the precious time that he spent here. Everything here in which Pavlov was concerned had its strictly defined co-ordinates in time and space, and these

were strictly adhered to. Even the simple motor-car ride to town was made into a sacred ritual, stop-watch in hand.

One could feel that people here loved nature and loved sunshine. The frontages of the numerous buildings faced the sun, the sunshine was enjoyed in the form of baths. Both people and animals rejoiced in it.

Koltushy, as a scientific station, had its beginnings as far back as 1920, first of all in an old landowner's house, but being later transferred to the other shore of the lake.

The original aim of Koltushy was to build a base for feeding and rearing animals for Pavlov's experiments in the Leningrad laboratories, as well as to provide a site for a summer rest home for the scientific workers of the laboratory.

Subsequently, Pavlov considerably extended the functions of Koltushy, founding here, in accordance with the plans that he himself drew up, a laboratory for the experimental genetics of higher nervous activity.

This is not, however, a genetics station in the usual sense of the word. Pavlov only applies the methods of genetics to purely physiological problems.

It would be quite incorrect to see in the scientific researches at Koltushy something that could be already *immediately* applied to practical medicine or animal breeding. At the same time there is no doubt that many phenomena for the study of which Pavlov laid the foundation here, contain in germ the essential requisites for subsequent tremendous advances in our knowledge of heredity, and in particular the heredity of mental diseases.

I paid a visit to Koltushy in July 1935, when Pavlov had just recovered from the effects of the serious influenza attack that he had suffered from in the spring. He was still not altogether satisfied with his state of health, but he was cheerful and full of plans for his journey to England to attend the Neurological Congress, although the inflammatory process in his ear was by no means at an end.

When I arrived he was seated in a deep leather arm-chair in his little study, a room on the first floor, and was busy reading.

This being my first visit to Koltushy, Pavlov, with great enthusiasm, although not with his old strength of voice, began to tell me about the work which he intended to perform. He was in agreement that a sort of natural selection should be made to operate among the enormous number of dogs that had recently passed through his laboratory, and that this selection should take place during the first period of organization of the Koltushy Station. He also agreed with the opinion I expressed, based on experiments with puppies, that strength and balance in the type of higher nervous activity are essential factors in the process of selection.

But his greatest interest was in the experiments on the anthropoid apes, and he related in detail the state of his researches on Rafael and Rose.

Comparing the achievements of these anthropoid apes, and in particular of Rafael, with various forms of human behaviour, Pavlov was attempting to throw light on the question as to what constituted the new quality introduced by *language* in the everyday cerebral activity of man. The book that lay on his knees was Locke's *Essay on the Human*

Understanding. But from what he said I gathered that it did not greatly satisfy him, any more than Ribaut's book *The Origin of Abstract Ideas*.

It is well known that Pavlov did not admit of any verbal "playing at ball," as Tolstoy called the small talk of conversation. Even as an "easy" subject of conversation at tea-time in the dining-hall, he selected the problem why the *Gestalt* theorists do not recognize association as a *basic* form of cerebral activity.

In his opinion, the conditioned reflex is a very convenient and successful form for the study of associations, owing to the fact that it is based on replacing *essential* qualities of the object or connections of the latter with the surrounding environment, by *unessential* qualities formed by way of temporary connection. He was indignant that the *Gestalt* theorists did not accept association as an elementary *analysis* which is followed by *synthesis*, and still further by *generalization*, and finally by *analogy* (as, for instance, when a dog differentiates not merely an interval in one part of the musical scale as first established but all such intervals in other parts of the scale). All these are undoubtedly powerful means for becoming acquainted with the interaction of objects and forces of external nature, and, at the highest level, of becoming acquainted with constant and not accidental relations, *i.e.* natural laws. In short, Pavlov was preparing to launch a devastating attack on the *Gestalt* psychologists at the Congress which was to take place next year. This desire of his, however, was destined to remain unrealized.

The time came to take a walk. Pavlov put on his straw hat and, accompanied by his son, we set out to

look at the garden and at the newly-constructed cottage which had just been completed.

Coming out on to the porch, we noticed that many plants were still in full bloom. Seeds were flying in the air, scattered hither and thither by the wind. Pavlov turned towards the large cage containing the anthropoid apes, and Rafael joyfully greeted him by powerful blows of its hand on the ground, accompanied by a benevolent bellow. Pavlov said in a friendly tone, "How do you do, Rafael?" and pointed out to us that during this primitive laughter of her companion, Rose was hiding herself behind the cross-beams of the ceiling.

We then went into the flower garden, Pavlov walking with a rapid limping gait, and we looked at the rows of climbing nasturtiums which, together with bushes of pink wild briar, lined both sides of the path.

But Pavlov loved not only nature but also art, including architecture. In spite of his feeble heart after his illness, Pavlov mounted to the upper balcony and made us come with him.

He demanded that the cross-bars should be removed from the windows so that nothing would prevent full enjoyment of the view over Koltushy (Fig. 25).

"How beautiful this white building will look on the background of the eternal green of the pines. It would be a good idea to cover the roof with tiles," he remarked. After Pavlov's death, Koltushy remains as his best monument.

* * * * *

Pavlov continues to live in his works. He left behind a tremendous school. It must be pointed



FIG. 25. The upper part of the laboratory building in Koltushy, with Pavlov's motto

out that two, or more correctly three, fundamental trends can be traced in the school of our most eminent modern physiologist; they correspond exactly to the basic fields of physiology in which Pavlov was successively engaged in the course of his creative activity and which to a great extent he reconstructed on new lines.

The first field contains the first and oldest group of Pavlov's pupils, those who are working on questions of *digestion* and the theory of internal secretion. This group includes V. Savich, G. Volborth, I. Tsitovich and to some extent M. Petrova and I. Rozenkov, the latter of whom has also occupied himself successfully with problems of so-called neurohumoral correlation.

The second scientific group arises from Pavlov's work on the so-called trophic innervation of organs, especially the innervation of the cardiac and other muscles; this group includes the academicians L. Orbeli and A. Speransky, who in their turn have already trained a whole galaxy of pupils.

Finally, mention must be made of the most numerous group of Pavlov's pupils, those trained during the last thirty-five years of his life when he devoted himself exclusively to studying higher nervous activity in all its diverse manifestations. The representatives of this group also include some of the older collaborators of Pavlov who entered the laboratory during the first decade of the century, *e.g.* N. Krasnogorsky, G. Zeleny and N. Nikiforovsky.

From the second decade came M. Petrova, P. Kupalov, N. Podkopayev, I. Rosenthal and the author of this book.

The third decade produced A. Ivanov-Smolensky,

L. Andreyev, K. Bykov, B. Birman, V. Rikman, P. Anokhin (who also occupied himself with questions of embryo-physiology), K. Abuladze, L. Fedorov (the Director of the Institute of Experimental Medicine), F. Mayorov, N. Nikitin, G. Skipin and V. Golovina.

Finally, the fourth decade has already given us Denisov, Asratian, A. Lindberg, V. Fedorov, S. Kleshov, Zeewald and others.

If we estimate the number of their works, we obtain a steadily rising curve. But the essential point, of course, is not one of chronology or statistics, but the *individual* character of each investigator, the diversity of the interests which each of these pupils derived from Pavlov and still more the varied fields of research undertaken by them. It is quite clear that the study of the physiology of behaviour is a field which itself is extraordinarily many-sided and sends out branches into many adjacent scientific subjects such as medicine, pedagogics, etc.

The majority of the authors of the numerous works carried out by the method of conditioned reflexes were *physicians*, *i.e.* they came to Pavlov from the clinic and were inspired first of all by the interests of their speciality, the treatment of human diseases. The same applies to Pavlov's collaborators during the first half of his life, those who worked with him on the problems of digestion. But many, when they had once come into his laboratory and remained in it under the spell of the mighty stream of Pavlov's ideas, left the clinic altogether and devoted the rest of their life to physiological theory, which according to Pavlov forms the most solid foundation for medicine.

Others, *e.g.* Krasnogorsky and Ivanov-Smolensky, did not break their connection with the clinic and attempted to apply the data obtained in the laboratory to the problems and requirements of medical treatment. But there were also those who endeavoured to apply the knowledge acquired by them in the laboratory to the analysis of normal activity in children, to problems of curing derangements of speech and even to music and mathematics.

The work of the above-mentioned Soviet scientists, performed by them by the method of conditioned reflexes, reflects the various directions taken by Pavlov's classical experiments and helps towards solving the basic problem put forward by Pavlov, the problem of acquaintance with the fundamental laws of activity in the development and pathology of the higher and lower centres of the brain.

Thus, recently K. Abuladze, in analysing the concept of the general working capacity or *tonus* of the cortex, has employed the method of simultaneously removing the visual, auditory and olfactory receptors, and he has investigated the brain processes on leaving untouched each one of the receptors in turn. Two conditioned reflexes were formed from different places of the skin; one was reinforced by eating, the other by pouring acid into the mouth. It was found that the cortex of animals that have been deprived of the normal impulses passing through the eye and ear, unlike that of healthy animals, is not able in one and the same day to perform these two diverse reflexes. That is to say, the working capacity of the cortex is extremely diminished after depriving it of the receptors. In this case there is no hint of any sharpening of perception; rather the chief role

in perception is transferred from the activity of the periphery to that of the cerebral centres, and the latter suffer to an extreme degree. It may be noted that normally the number of new connections in the dog's brain is unlimited.

Asratian has been concerned with studying the so-called *lability* of the cells of the cerebral cortex, and he has connected this with Lapique's theory of *chronaxie*, who is well known on account of his work in the field of general nervous physiology. Hence, the physics and chemistry of vital processes taking place in the organism is being linked up with the general physiology of the nervous system and with the higher cortical processes of which the conditioned reflexes are an indicator.

But, as is well known, the cortex does not only depend on vegetative processes occurring in the organism; to a certain extent it can also *control* them. This is indicated by the experiments with dogs conducted by Bykov who, together with Olniansky, established that any indifferent stimulus, *e.g.* a bell, if it is systematically "reinforced" by the introduction of *thyroxin*, a substance considerably increasing metabolism, would finally itself begin to produce increased metabolism in the organism.

The same formation of a conditioned reflex to a general vital activity of the organism and not to one particular function of it can be observed on introduction of *adrenalin*.

Ivanov-Smolensky, who has selected the age of childhood as the subject for experiments with conditioned reflexes, has carried out very interesting experiments of the same character. But, being concerned with children, he used, instead of a bell, some

common *word*. Here the utterance of the word, as the signal of some vegetative reaction, *e.g.* acceleration of heart-beat, could be entrusted even to the subject experimented on. Consequently the child as it were "commanded" a reaction about which it in general, *i.e. outside* the elaborated conditioned reflex, had no conception at all.

All this goes to show that, in the cerebral cortex both of animals and man, besides the previously mentioned analysers of the external world, there exists also a controlling centre over all our *vegetative*, bodily functions. This in its turn opens up exceptionally wide prospects for acting on these functions in the clinic by means of therapeutic suggestion.

A quite special sphere has been touched upon through the work of S. Kleshov, who has specialized in questions relating to music and musical theory. By the method of conditioned reflexes he has sought to discover the laws governing musical perception. He was naturally interested in the question whether the animal brain (*e.g.* of the dog) could react not merely to absolute pitch, which had already been proved, but to the relation between sounds, *i.e.* the interval between them. He established that such a relation could also become a conditioned reflex for salivary secretion. A musical interval from one part of the scale established as a conditioned reflex remains active on being transferred to other parts of the scale.

Two of the older of Pavlov's collaborators, N. Krasnogorsky and M. Petrova, were occupied during the last year of Pavlov's life in studying the origin of those peculiar states in animals that have many points of resemblance to psychical disorders in man.

We remind the reader that hitherto Pavlov's school had been concerned only with experimental neuroses.

Krasnogorsky recently showed that a convulsive fit in an animal caused by passing an electric current through its skull can also be brought on by means of a conditioned reflex, provided that the indifferent stimulus has previously been reinforced by the electric current. In the intervals between the fits of convulsions, a peculiar state of disorientation develops in the animal, with a tendency to aggression which is replaced by a profound lowering of excitability.

M. Petrova in her interesting researches has come even closer to reproducing experimentally various symptoms observed in the psychiatric clinic. For a long period she kept under observation a castrated animal which had a generally vigorous nervous constitution but which was given a task in regard to inhibition that its brain was not capable of performing. The result was that everything connected with the inhibition of stimuli became extremely difficult for the dog and proceeded to a very large extent in a pathological way.

Everyone is aware that walking along the edge of a precipice produces noticeable inhibition even in an experienced climber. A person unused to climbing, even if absolutely fit and healthy, feels a strong impulse in such cases to go on all fours, and his body seems to him as if filled with lead. In certain disorders of the brain the person afflicted finds it impossible even to cross an open space (agoraphobia).

Petrova's dog, after experiencing overstrain of the inhibitory process, began to behave in an exaggerated way even to imaginary dangers, as

represented, for instance, by a flight of stairs from the first floor, displaying a characteristic phobia, a terror of the edge of this diminutive precipice, pressing herself to the wall and not daring to take a piece of meat placed close to the banisters, and so on.

The experiments of A. Lindberg and F. Mayorov have been concerned with discovering the very delicate laws controlling the work of the cerebral cortex of an animal, particularly in regard to strength relations. Lindberg has shown by a simple but ingenious means that a strong external stimulus produces relatively big changes in the cortex, and that a neurone which has had its equilibrium disturbed returns to normal after a comparatively long period, although the variations in strength of the stimulus applied may have been comparatively small.

It should be mentioned that the question of mutual strength relations in the cortex was one in which Pavlov was extremely interested during the last year of his life, his interest being not only in the question of the strength of conditioned reflexes but applying also to unconditioned reflexes. In all his experiments he regarded measurements of strength, of degree, as being especially important. Wherever possible he endeavoured to express the results of an experiment in the form of a short formula. The connection of the physiology of higher nervous activity with general problems of present-day physiology also finds treatment in a number of reports of Pavlov's pupils to the last International Physiological Congress held in the U.S.S.R. in 1935. These reports were directed to showing that the theory of conditioned reflexes is one

of the most promising chapters of natural science, perhaps a rather complicated but nevertheless an extremely fruitful region of physiology.

The report presented by the present author to the Physiological Congress touched on one of the most general questions of all, the analysis of which demands the closest combination of the methods of the general physiology of the nervous system with the whole body of data obtained by the method of conditioned reflexes as well as with the data of the clinic, viz. problems relating to the *calculation of time* such as were briefly referred to above but which during recent years have been transferred from animals to man (work of my collaborator, A. Izergina).

But the work of Soviet scientists of course by no means exhausts the work that is being carried on at the present time by Pavlov's method of conditioned reflexes.

"It is difficult to make a correct estimate of the influence of Pavlov's theory on foreign physiologists, psychologists, neurologists and psychiatrists. One thing is clear, that this is the first instance of such a wide and yearly increasing interest being taken by foreign specialists in the scientific activity of our great savant.

"At the present time experiments using the method of conditioned reflexes are being performed in the following laboratories:

"U.S.A.: Ithaca (New York State).—Cornell University. The work of Liddell and his collaborators. Baltimore (Maryland).—The Laboratory for conditioned reflexes belonging to Adolf Meyer's Psychiatric Clinic. The work of W. Ganft and his collaborators. Some of the collaborators of Liddell

and Ganft are now undertaking independent work by the same method.

"Canada: Montreal.—MacGill University. Work is being carried on here by Professors Babkin, Gant and Collip. A special course is given to the students on conditioned reflexes.

"France: Paris.—The Lapicque Physiological Laboratory. Dr. Drobovich is investigating the connection between conditioned reflexes and chronaxie. In Toulouse, Professor Soula is applying the method of conditioned reflexes in researches on the functioning of the stomach.

"Poland.—Doctors Konorsky and Miller, working in the Warsaw Psychiatric Hospital, have for several years been vigorously pursuing systematic research into the higher nervous activity of animals and have obtained interesting and valuable results. Work on conditioned reflexes is also reported from the Physiological Laboratory of Cracow University.

"Japan.—In Tokyo, Professor Hayashi, who studied the method of conditioned reflexes in the Soviet Union, is working in the Physiological Laboratory of the University.

"The great French psychologist Dumas devoted a large chapter to conditioned reflexes in one of the volumes of his work on psychology. The president of the Society of French Morphologists, Doctor Thorez, is an enthusiastic supporter of the theory of conditioned reflexes. The world-famous neurologist and histologist, the Rumanian Professor Marinesco, is developing the understanding of hysteria from the point of view of conditioned reflexes. The eminent American psychiatrist, Adolf Meyer, has organized a laboratory for conditioned reflexes in connection

with his clinic, and has himself made a detailed study of the work conducted in the Soviet Union.

"The American neurologist, Doctor Leyman, working in Pekin, previously studied the method of conditioned reflexes for some years in my laboratory.

"Great Britain occupies a very special place in relation both to the theory of conditioned reflexes and to the creation of this theory. All possible marks of scientific distinction have been conferred on Pavlov. Not only specialists in physiology, psychology and neurology, but all scientists in general are to a greater or lesser extent acquainted with the theory of conditioned reflexes.

"In the physiological laboratory of Cambridge University, on the initiative of Professor Barcroft, research has been organized employing the method of conditioned reflexes.

"Thus we see that the theory of conditioned reflexes has been assimilated outside the Soviet Union by very widespread and diverse circles of scientists and physicians."¹

What are the further prospects of development of Pavlov's great theory?

It must be mentioned that the achievements of the physiological school in various fields that were covered by Pavlov's genius are already being widely utilized. Some of these fields are directly connected with the name of Pavlov. One such is that of the physiology and pathology of cardiovascular activity in connection with the theory of the "strengthening" cardiac nerve, which has laid the foundations for the

¹ The data on work outside the U.S.S.R. have been taken from the article of I. S. Rosenthal devoted to the 85th anniversary of Pavlov's birth.

modern theory of trophic nerves. Further, we have the application to the surgery of the gastrointestinal tract of the study of the mechanism of secretion of the gastric juices. Here brilliant prospects have been opened up for physicians in regard to treatment of various disorders that previously could not be influenced. Incidentally, one sees here the enormous significance of Pavlov's work for physicians and clinicians.

Finally, Pavlov's latest work in the field of nervous and psychiatric diseases, in particular his experiments on treatment of psychoneuroses, and during the last year on the treatment of schizophrenia by prolonged sleep, has shown that Pavlov, who was a physician by education and a physiologist by speciality, never ceased to be a clinician. He was distinguished from other medical theorists by the fact that he understood the word clinic in a very wide sense and that, in developing his experimental work on animals, he always had in view the interests of suffering human beings.

Pavlov took an especially great share in the creation of Soviet neurophysiology and medicine, being the founder of the objective method of study of the activity of the higher regions of the central nervous system.

The conditions under which Pavlov carried on his work in the pre-revolutionary period, covering almost a quarter of a century, do not bear comparison with those conditions for the development of his work created by the Soviet government. Apart from the two enormous institutes in the All-Union Institute of Experimental Medicine and in the Academy of Sciences, there has been constructed

and equipped a whole scientific township near Leningrad—the Koltushy Biological Station (now named after Pavlov)—devoted especially to research on the genetics of higher nervous activity. Pavlov gave it the task of working out problems of variation and inheritance of the types of nervous activity, a subject having a close bearing on the prevention of mental diseases.

All this, however, is only a small part of the tremendous work which is now being carried on throughout the world on the basis of Pavlov's ideas and which is destined to continue his classical scientific tradition. Many world-famous neurological schools, as we have seen, are experiencing the influence of Pavlov's great ideas. Even those modern clinicians who are opposed to his views on the possibility of the physiological understanding of neuroses, have been obliged by his work to perform experiments no less careful and no less profound than those of Pavlov himself. Consequently we witness an increase in the extent of experimental investigation and a rise in the general level of treatment of the object of research.

Modern pedology, pedagogics, pharmacology, not to speak of physical culture, the physiology of feeding and the physiology of labour, all bear the impress of Pavlov's discoveries.

In our country, surging with new life, where every day new prospects are opened up for the application of science, the thoughts of physiologists are inevitably directed to the basic problem of the origin of the higher nervous activity of man. To study the laws of evolution of the brain so as to learn to control them and so as to cure and prevent pathological

disorders—such is the basic task that confronts us today.

In this respect Pavlov's theory of conditioned reflexes and his last researches must be regarded as a highly important stage in the development of our knowledge of the evolution of the cerebral cortex, of which the highest system in Pavlov's sense of the word, viz. the human brain, has created and is creating natural science.

We know that natural science, like scientific thought in general, is a superstructure on the economic interrelations which form the basis of all human activity.

Backed by the universal support of the country where socialism is being built, Pavlov, through his powerful experimental genius, heightened by his fighting temperament, laid the most lasting foundations both for the study of changes in the functions of the brain and for the study of the mutual relations of inborn and acquired reflexes. From this it was a simple matter for him to make the next step to the treatment of certain nervous and mental diseases.

Comparing the two most important trends in biology and physiology—the theories of Darwin and of Pavlov—we are justified in expecting that it is precisely here that we should look for the solution of many acute problems. All the efforts of physiologists of the nervous system, and particularly of Pavlov's pupils, should be directed to this question.

It may be that we are still powerless in the struggle against death and disease, and especially against the death of such a man as Pavlov. We who are deprived of his immediate leadership must think, and

are thinking, of the great future chapter of natural science that will be based on his work.

Pavlov had a wide humanist outlook not only in science but also in his estimate of the problems immediately confronting all peoples. At the opening of the International Physiological Congress in Leningrad on August 9, 1935 (Fig. 26), he declared: "War is by its nature a bestial method for solving the difficulties of life, a method unworthy of the human mind with its immeasurable resources. I am happy that the government of my great fatherland in its struggle for peace has proclaimed for the first time in history, 'We do not seek a foot of foreign soil.'"

In our remembrance of this world-famous scientist, one of the best sons of the Soviet land that he so greatly loved, we must not forget this great protest against war, this call to the ultimate rational unification of humanity.

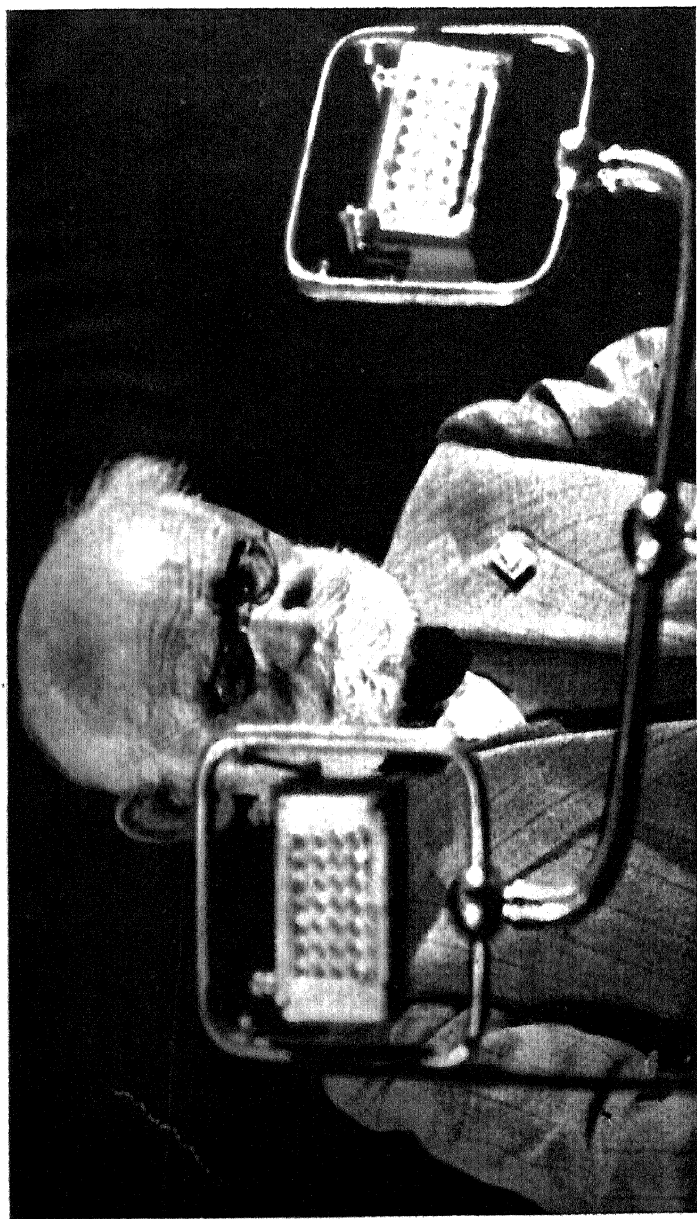


Fig. 26. I. P. Pavlov on the platform at the Fifteenth International Congress of Physiologists in August, 1935

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